

Tool Making

Part III

1.85

Prepared especially for the instruction
and training of students of the
American School

By

Edward R. Markham

Instructor in Shop Work, Harvard University and Rindge Technical School
Consulting Expert in Heat Treatment of Steel
Formerly Superintendent, Waltham Watch Tool Company
American Society of Mechanical Engineers

American School

Chicago

U.S.A.

COPYRIGHT, 1916, 1920, 1922, 1924, 1927, BY
AMERICAN SCHOOL

COPYRIGHTED IN GREAT BRITAIN
ALL RIGHTS RESERVED

TOOL-MAKING

PART III

STANDARD TOOLS—(Continued)

DRILL JIGS—(Continued)

Fastening Devices. Various devices are used to fasten the leaf of a jig to hold the work in place, or to clamp the leaf in position. The forms used depend upon the class of work being operated on.

If the leaf must be fastened solidly, and the amount of time consumed is not of great importance, some form of *screw clamp* may be used; but if the work must be handled rapidly, the clamping device is generally operated by some form of cam. However, a screw

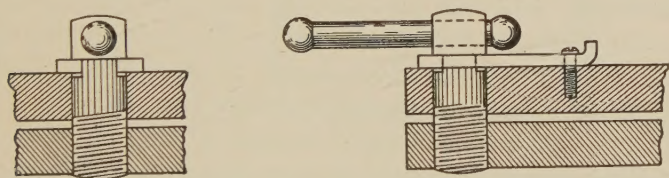


Fig. 291. Screw Clamp for Jig

clamp may be designed to work quite rapidly, and such a one is illustrated in Fig. 291. This screw clamp consists of a screw with a hole drilled through it to receive a pin that is used as a lever to operate the screw. The screw is necked $\frac{1}{16}$ inch deep, the necking being $\frac{1}{8}$ inch wide; a flat washer is attached to the leaf of the jig by a small screw, as shown. A slot the width of the screw is cut in this washer to allow it to slide back and forth, and in the end of the washer is a slot the width of the bottom of the necking in the screw. The other end of the washer is turned up, as shown, to furnish a means of pushing back and forth. When the jig leaf is closed, the washer is pushed forward and the ends engage in the slot in the screw. One turn of the screw binds it very tightly. When the screw is given one turn to loosen it, the washer may be pushed back and the jig leaf raised.

Where it is not necessary to use much power, but extreme rapidity of action is desired, a *hinged cam lever* of the design shown in Fig. 292 may be used. The cam lever is pivoted to the base of the jig by means of a pin as shown. The lever passes into a slot

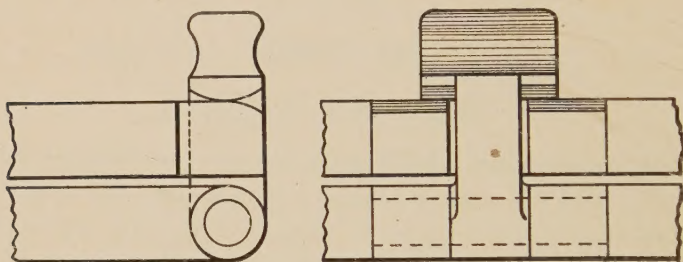


Fig. 292. Hinged Cam Lever for Jig

in the leaf, and the bearing surfaces on the under part of the head come in contact with the inclined surfaces at the end of the leaf.

Bushings. Bushings of hardened tool steel are made as a permanent guide for the cutting tools. The hole in the bushing is made to fit the cutting tool that is to be guided. There are various forms of bushings; the plain straight form, Fig. 293, is sometimes used, but is objectionable because it may be pushed into the jig if the cutting tool is too large to pass through the hole. To overcome this tendency, bushings are sometimes made tapering on the outside, as shown in Fig. 294; but as this is an expensive form, and as it is an extremely difficult operation to bore the bushing hole in the jig, it is not generally used for permanent bushings.



Fig. 293. Bushing with Straight Outside

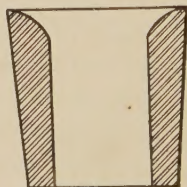


Fig. 294. Bushing with Tapering Outside

The most common form of bushing is straight, with an enlarged portion or head. When no allowance is made for grinding on the outside, the bushing is usually made in the form shown in Fig. 295. If the shoulder under the head is square, it is likely to crack at the sharp corner, or the head may be broken off when being forced into position. In order to avoid these difficulties, a fillet is left under the head, as shown in Fig. 296.

Grinding. When it is essential that the location of the drilled hole or portion of the piece being machined in the jig be exact, the tool must fit well in the bushing; and as the size and shape of the bushing are likely to change in the hardening, it is advisable to leave enough stock to grind to size, both inside and out. It is essential that the outside of the bushing be exactly concentric with the inside. After the hole is ground and lapped to size, the bushing may be placed on a mandrel which runs true, and the outside ground to size. When machining a bushing which is to be ground on the outside, it is necessary to neck in, under the head, as shown in Fig. 297, in order that the emery wheel may pass entirely over the part being ground and insure a straight surface. The under side of the head which

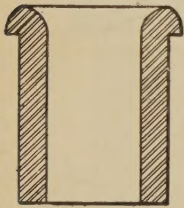


Fig. 295. Common Bushing

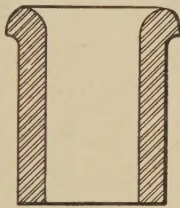


Fig. 296. Bushing with Fillet under Head

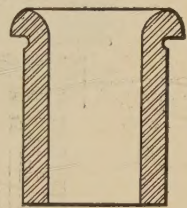


Fig. 297. Necked Bushing

rests on the upper surface of the jig should be ground so that it may be true with the surface of the jig.

When grinding a bushing, a mandrel should be used which is straight or of very slight taper and has been tested for trueness. If the taper is considerable one end of the hole in the bushing will not fit, and the outside of the bushing will not be concentric with the hole. Consequently, no matter how careful the tool-maker may be in laying out his work and in boring the holes for the bushings, the jig will not be accurate.

Size of Bushings. The outside diameter of a bushing is often determined by the design of the jig; for instance, two holes are often located so near each other that it is impossible to make the bushings much larger than the holes through them. Whenever possible, the outside diameter should be made enough larger than the hole to leave a reasonably thick wall. A bushing with thin walls is likely to close in when being pressed to its seating; also, if a cutting tool binds in a bushing with thin walls, the bushing turns in the jig.

Removable Bushings. It is sometimes advisable to perform two or more operations in the same jig. After a hole has been drilled, it may be that it will be considered good practice to counter-bore or tap it, or, possibly, it may be better to do the three operations while the work is seated in the jig. In such cases the bushing having a hole the size of the drill must be removed, and one inserted that has a hole fitting the tool to be used.

A very simple way of making a removable bushing consists in boring the hole in the jig large enough to receive a hardened bushing with a hole the size of the outside of the bushing to be used. If the hole in the large stationary bushing and the outside surface of the removable bushing are lapped smoothly after grinding, they

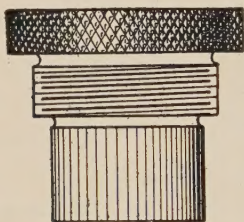


Fig. 298. Threaded Bushing

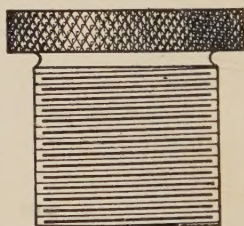


Fig. 299. Removable Bushing, Threads Run Entire Length

may be used for a long period before wearing enough to affect appreciably the location.

Tapered removable bushings are sometimes used, but on account of the expense of producing them, and the fact that chips and dirt readily throw them out of their true locations, they are not very common and their use is not advised.

Fig. 298 shows a form of removable bushing threaded on the outside to fit a threaded hole in the jig. If the thread on the outside of the bushing runs the entire length, Fig. 299, the process of screwing it in and out of the jig is necessarily very slow; consequently it is advisable to have but a few threads. The balance of the length may be made to fit a bearing in the jig. If it is advisable to thread the entire length, the hole should be ground true with the thread to prevent change of shape in hardening. As it is not well to attempt to grind between the lands of the thread with the facilities in the ordinary machine shop, it is necessary to grind the hole true with the thread. This can be done satisfactorily by placing a piece of

stock in a chuck on the lathe having a grinding attachment. After drilling and boring the hole to tapping size, the thread should be chased so that the bushing is a good fit in the hole. It can then be screwed in, and the hole ground to size.

Box Jig. If the piece of work is of a shape that makes it necessary to operate on all sides, and the outline prevents the use of a clamp jig of the form shown, a box jig must be used. A box jig is made in the form of a box, the piece being located in the jig by means of stops or locating points which differ according to the nature of the work. It is often advisable to design this form of jig so

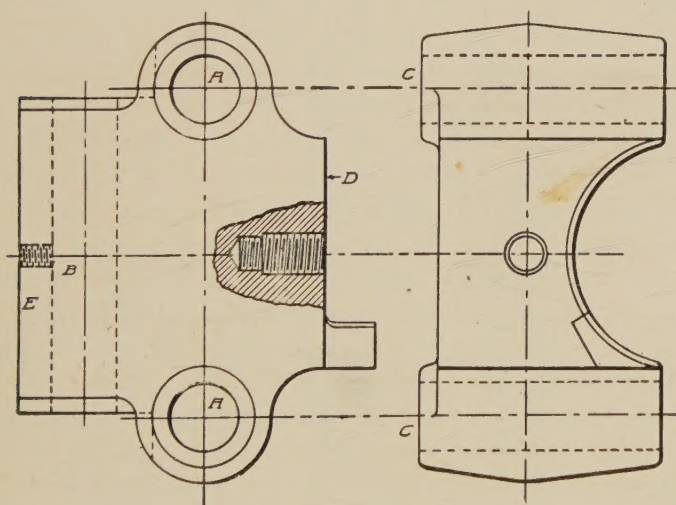


Fig. 300. Special Piece to Be Drilled

that all holes in the work can be drilled at one setting; that is, if there are twenty holes in the piece, it is designed to allow the drilling of them all while the piece is in the jig. For other work it is advisable to make two or more jigs to drill the holes; this is the case when some part of the piece is to be machined after one or more holes are drilled, but before drilling the others.

In Fig. 300 a piece of work is shown (about three-eighths size); through the piece it was necessary to drill three 1-inch holes as shown at *AA*, and *B*. As the holes *AA* must be an exact distance from *B*, it was found by experience that much better results could be obtained if the hole marked *B* was drilled and reamed in a jig,

the piece taken out of the jig, and the portions marked *CC* milled in exact relation to the hole *B* and as nearly as possible at right angles with the side of the casting marked *D*. After the portions *CC* had been milled, the piece was placed in another jig, locating it by the hole *B* and the surfaces *CC*; the holes *AA* were then drilled and reamed. In order to drill the hole *B*, the jig shown in Fig. 301 was used. The piece was placed in the jig with the rounded surface *E*, Fig. 300, resting in two V-blocks, *A*, Fig. 301.

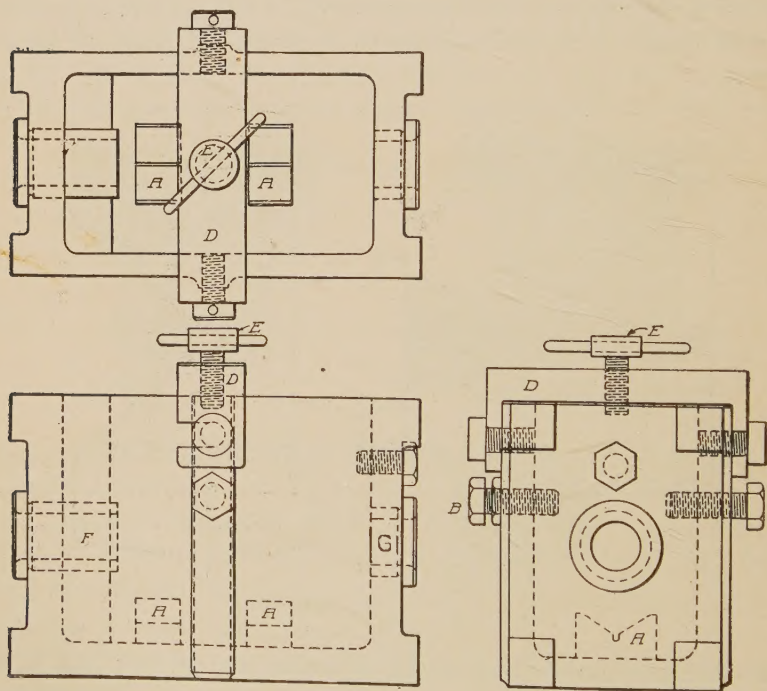


Fig. 301. Jig for Work Shown in Preceding Figure

It was located by means of the fixed stop screw *B*, and forced against *A* by the screw; it was held in position by the screw *E*, which was located in the strap *D*, this strap being removed when putting a piece of work in the jig or taking it out. As it was necessary to have the hole straight and true with the locating points, it was reamed with a single-lip reamer having a pilot, Fig. 302. The hole was drilled somewhat smaller than finish size ($\frac{1}{64}$ inch), and the reamer was entered in the hole, the pilot fitting the bushing *G*. While

the body of the reamer fits the bushing *F*, as previously explained, the single-lip reamer acts on the same principles as a boring tool used in the engine lathe, the result being a hole straight and true.

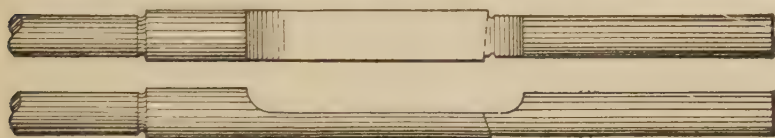


Fig. 302. Single-Lip Reamer with Pilot

As it was necessary to have the hole in the upper bushing of the size of the body of the reamer, and as a drill $\frac{1}{64}$ inch smaller than this size must be used, it was advisable, in order properly to start the drill, to use a transfer drill, shown in Fig. 303, the cutting portion *A* being the size of the drill to be used in making the hole, while *B* fitted the hole in the bushing. By means of this drill, a hole the size of the drill to be used was started in the casting, perfectly true with the hole in the bushing, yet somewhat smaller. When the hole had been drilled to a depth of $\frac{3}{16}$ or $\frac{1}{4}$ inch, the transfer drill was removed, and a twist drill of the proper size used to finish. When the piece of work was taken from the jig, the portions marked *CC*, Fig. 300, were milled as explained. The piece was then placed in another jig, and a pin fitting the reamed hole passed through the locating bushings and through the hole; by this means the other two holes could be accurately located and drilled. The second jig so closely resembles the first that it is unnecessary to illustrate it.

Jig for Holes around Circular Shaped Pieces. At times, it is essential to design a drill jig for drilling holes, either equally or

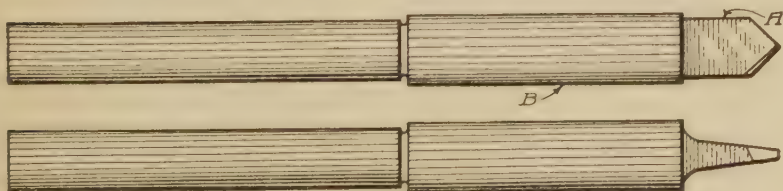


Fig. 303. Transfer Drill

unequally spaced, around a circular shaped piece of work, such as the six equidistantly spaced holes around the circumference shown in Fig. 304. These holes are all radial; but a jig of this type

may be designed to drill holes that are not radial, or it may be designed to drill a number that are radial and others that are not

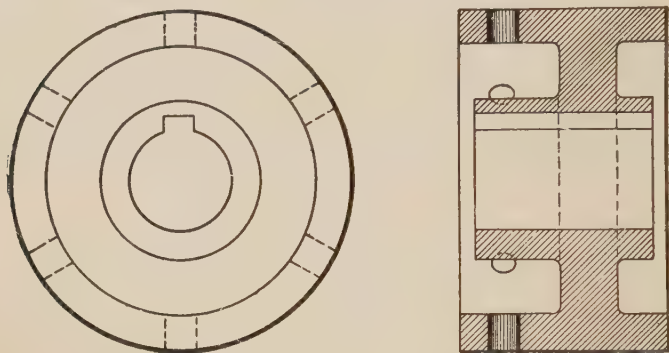


Fig. 304. Drilling around Circular Piece

radial by locating the bushings to produce the holes in the desired locations.

Fig. 305 shows a jig with but one bushing designed to drill the six holes in the piece shown in Fig. 304. The spacing of the holes is determined by the index plate *A*, while the work is held on the stud *B*. As the holes must be accurately located with the keyway in the piece, the stud in the jig is provided with a key to fit the keyway. The dial plate being keyed to the stud *B*, the holes

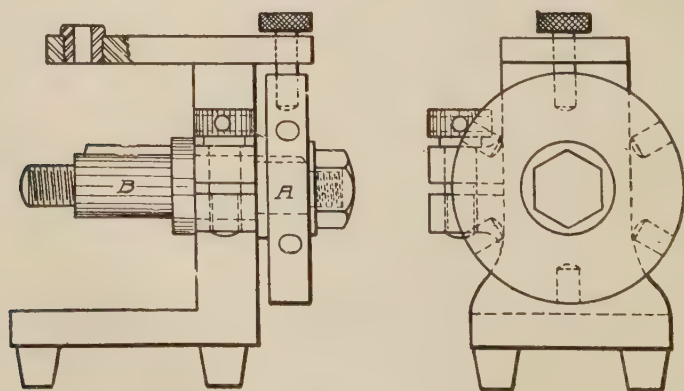


Fig. 305. Jig with One Bushing to Drill Six Holes

drilled in any number of pieces will all exactly correspond with the location of the keyway and with the holes in all of the other pieces.

While the dial shown on the jig in Fig. 305 is designed to drill six evenly spaced holes, the holes in the edge to receive the locating pin might have been cut in any desired number and have been spaced to produce holes of an uneven distance apart.

If large drills are to be used in connection with the jig, it is advisable to provide some method of binding the stud to prevent any strain on dial and pin for such a strain would tend to render the jig inaccurate after it had been used for a time.

In the case of the jig shown, the portion of the body of the jig that provides a bearing for the stud is split and supplied with a binding screw and lever. The stud should be securely locked in position each time the piece is turned to locate a hole to be drilled.

If holes are to be drilled at different distances from the shoulder, two or more bushings may be provided. If the holes are all of one size, such an arrangement of bushings may lead to error unless the locating hole on the dial is so stamped that the operator can by looking at it as the pin enters, see which bushing the drill should enter.

This form of jig is capable of almost endless variation of design, and can be made to accommodate not only pieces that are round in form, but those of almost any form where holes are to be drilled around the outer surface. In some shops the work is of such form and the holes are so arranged that many jigs of different design are not necessary, but all of above types are used.

PUNCH AND DIE WORK

Dies. A die used for punching a blank from a sheet of metal is termed a blanking die, and is generally considered as belonging to one of three classes: plain (or simple) die, gang die, or compound die.

A set of blanking dies consists of a male die, or *punch*, and a female die, or *die block*. The die block is that part of the die which has a hole of the same outline as the desired blank; the male die, or punch, is of a shape that fits the impression or hole of the die block.

When punching work on a punching press, the stock is placed on the die and the punch forced through it into the die; this drives a piece of stock of the same outline as the hole down into the die

block. As the punch is forced through, the metal in the sheet has a tendency to close on the punch and to be raised by it. In order to prevent this, the die block is provided with a *stripper plate*, or *stripper*, which is fastened to the die, or to a shoe holding the die, at a height that allows the metal to be punched to pass freely between it and the die. The stripper must be strong enough to force the stock from the punch without springing, especially if the punch is slender and the stock thick, for if it did not, the punch would be sprung or broken.

In order to guide the stock over the die and leave the proper amount of margin or scrap at the edge of the sheet, a *guide* is furnished. The guide is usually made of stock sufficiently thick to bring the stripper the proper height above the face of the die. A *gage pin*, or *stop*, is usually provided, so located that the proper amount of scrap is left.

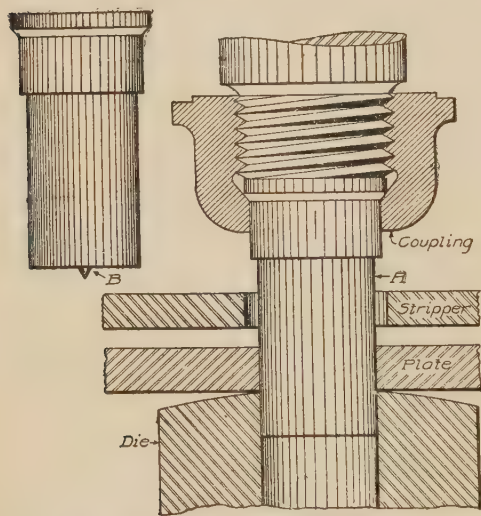


Fig. 306. Punch for Boiler Plate Showing Locating Point

workman lays off and prickpunches the sheet where each hole should be; the sheet is then taken to the punch press, and each hole is punched as laid off.

Punches for Large Holes. In Fig. 306, *A* is the form generally used for punching large holes, or for heavy material. If the face of the die is made flat, it is necessary to shear the punch. The die is made round in form, as shown, and is held in the bolster by means of a round-end set screw which enters a cut on the side of the die near the bottom.

Boiler Plate Punches.

Punches for use on boiler plate and similar material are made with a locating point as shown at *B*, Fig. 306. This point enters a prickpunched mark, and so locates the sheet for punching. The

In Fig. 307, *A* is the die block, *B* the hole through the die block of the shape of the piece to be punched, *C* the stripper, *D* the guide, and *E* the gage pin or stop.

Die Holders. Dies are held in position on the punching press bed by various methods, the most common of which are the forms

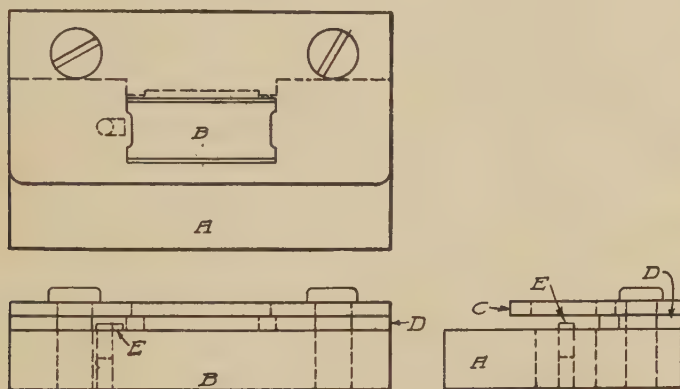


Fig. 307. Punching Die

of holdfast shown in Figs. 308 and 309. These die holders are known by various names, such as chair, bolster, and chuck. Large dies are clamped to the bed of the press.

Dies are usually beveled on the edges that come in contact with the die holder, to prevent their rising from the seat. The angle given to the edges varies according to the ideas of the designer. An angle of 10 degrees from the vertical gives satisfaction, although some mechanics insist on an angle of 15 degrees or even 20 degrees.

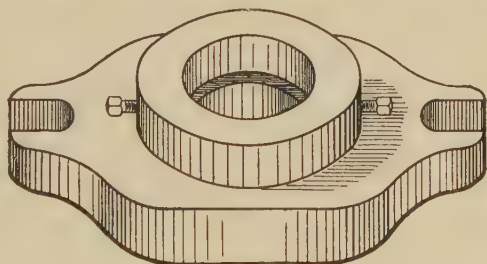


Fig. 308. Form of Holdfast

Fig. 310 shows a die holder with a die whose edges are at an angle of 10 degrees; the die is held in place by set screws. It is generally considered advisable to place a gib, or shim, between the set screws and die as shown. Sometimes the gib is omitted, and then the set screws bear directly on the edge of the die. Some

tool-makers prefer a die holder without set screws, and hold the die securely in place by the gib, which is made wedge-shaped and is driven to place.

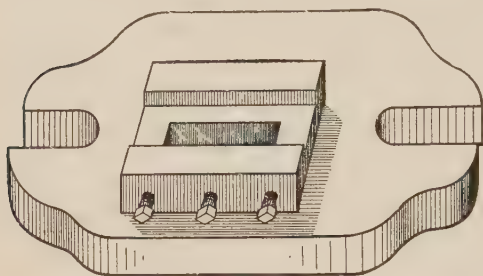


Fig. 309. Form of Holdfast

are then brought against the edge of the die, or against strips of steel which are placed between them and the edges of the die.

Making Die. *Preparation of Bar.* When making several dies of equal width and thickness, a good method is to plane the two sides of a bar to remove the outer surface and to bevel the edges to the required angle.

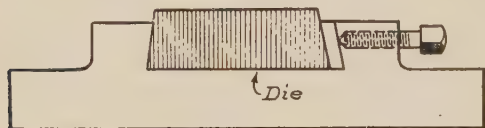


Fig. 310. Die in Holder

finished smooth by planing with a smoothing tool; it may be ground in a surface grinder, or it may be finished with a file. It is necessary to have the surface smooth in order to lay out the correct shape of the hole; a roughly machined surface would allow neither distinct nor



Fig. 311. Easily Set Die Holder

correct work. The die must be laid out in such a manner that the stock may be readily fed to it. If the grain of the stock is a matter of importance, as in making a tempered spring, the worker must take care to see that the grain runs in the proper direction.

Marking and Drilling. The face, or upper surface, of the die is covered with the blue vitriol solution, and the outline of the piece to be punched is laid out. After the die has been carefully laid

Fig. 311 shows a method of holding dies which allows them to be easily set in position when rigging up. The die is placed on the seating of the die holder, and brought to the proper position. The set screws

Pieces can then be cut off to any length wanted.

The upper surface of the die bar may be finished smooth by planing with a smoothing tool; it may be ground in a surface grinder, or it may be finished with a file. It is necessary to have the surface smooth in order to lay out the correct shape of the hole; a roughly machined surface would allow neither distinct nor correct work. The die must be laid out in such a manner that the stock may be readily fed to it. If the grain of the stock is a matter of importance, as in making a tempered spring,

out from a templet or drawing, all round corners should be drilled with a drill of proper size; they are then reamed from the back side of the die with a taper reamer to give the desired clearance, and the balance of the stock is removed by drilling, as shown in Fig. 312.

The method of removing the center, or core depends on the custom practiced by the individual die-maker. One die-maker may drill the holes so that they break into one another, and for him the best tool is a straightway (straight fluted) drill. Another will drill

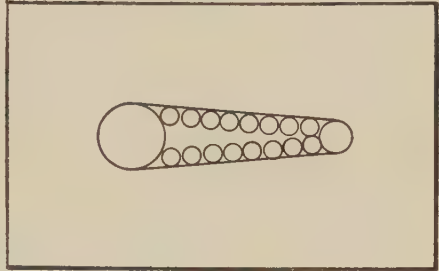


Fig. 312. Removal of Stock by Drilling

small holes and use a counterbore to enlarge to size, the counterbored holes breaking into each other. Usually the holes are drilled with at least $\frac{1}{16}$ inch to $\frac{1}{32}$ inch between them, and the intervening stock is cut out with a flat-ended hand broach, Fig. 313. Generally speaking, the last mentioned method is the safest and quickest.

Milling. After the center has been removed, the die may be placed in a die milling machine or a die sinking machine; and by the use of a milling cutter of the proper taper, the desired angle of clearance can be given. The amount of clearance varies with the nature of the work to be done.

When a die is milled on a die milling machine of the form shown in Fig. 314, the cutter spindle is underneath the die, the face of which is uppermost; consequently the milling cutter can be made largest at the shank end of the cutting part, the required taper

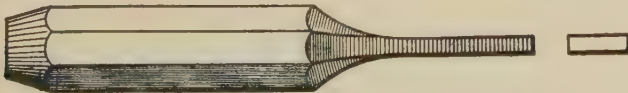


Fig. 313. Flat-End Hand Broach

being given as shown in Fig. 315. If the outline of the hole is milled on a die sinking machine, it is necessary to use a cutter of the shape shown in Fig. 316, in order that the face of the die having the lines will be uppermost.

Filing. After working the impression as near to shape as possible by milling, it can be finished by filing. In order to give

the die the proper clearance, the walls should be gaged with a bevel gage of the form shown in Fig. 8, Part I. As the clearance differs in various shops, and on different classes of work, no stated amount can be given for all cases; it varies from $\frac{1}{4}$ degree to 3 degrees. The latter is excessive, and is seldom given unless it is necessary that the piece punched drop from the die each time.

If the die is milled as just described, it will be necessary to work all corners to shape with a file. If a universal milling machine having a slotting attachment is used, the corners can be properly shaped and the necessary clearance given by using suitably shaped cutting tools, and turning the fixture to the proper angle.

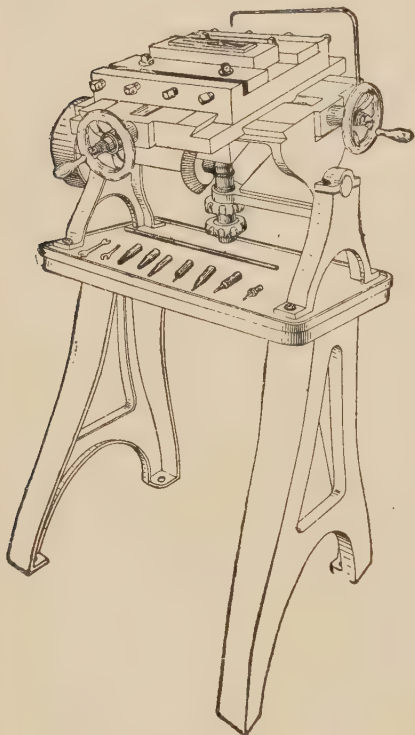


Fig. 314. Die Milling Machine

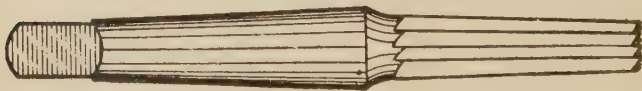


Fig. 315. Die Milling Cutter

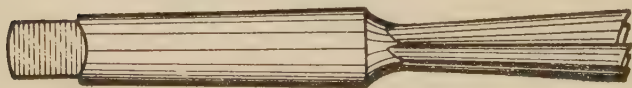


Fig. 316. Cutter for Die Sinking Machine

Fig. 317 shows a slotting fixture attached to a universal milling machine; while Fig. 318 shows a fixture known as a die shaper, which is also attached to a milling machine.

Die Filing Machine. In many shops the die filing machine, shown in Fig. 319, is used for many of the operations of working to shape dies, gages, templets, and various small parts. It is also used in lapping dies, gages, and models, which have been hardened. As the table of the machine can be set at an angle, dies can be filed or lapped at the proper angle to give the desired clearance.

A saw may be used in place of the file, and the core of the die sawed out; this is a very satisfactory way of cutting the core from a small die having an irregularly shaped opening, whose outline

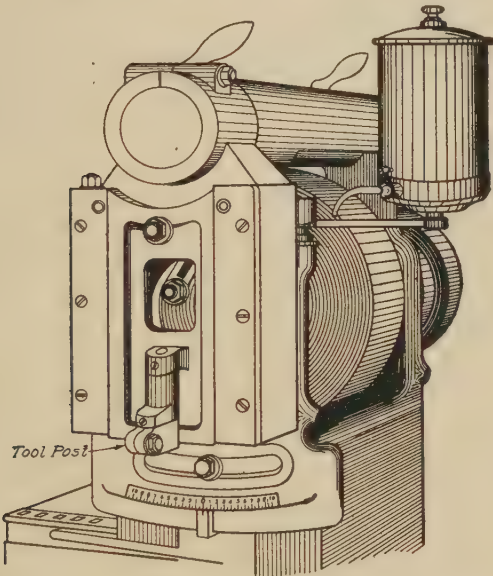


Fig. 317. Slotting Fixture on Universal Milling Machine

is such that the ordinary methods do not prove satisfactory, or are extremely costly. For large work, an ordinary hack saw blade may be used, holes being drilled at the corners of the openings. For small work and where irregularly shaped openings are to be produced, a narrow blade whose teeth have quite a little set is advisable.

For roughing out a die opening, a coarse file should be used, the file being clamped at either end, and the work held against it by means of the feed screw, while the die is guided by hand. When taking finish cuts with small files, the file is usually held in the lower clamp only. As the file clears on the return stroke, undue

wear is avoided. The crank pin may be set at either end of the crank arm, as may be desired, so as to cause the file to cut at either the up or down stroke.

Graduated table readings are furnished so that the table can be set to provide any angle of clearance. The surfaces produced by this machine are flat, and especially adapted to dies having but a

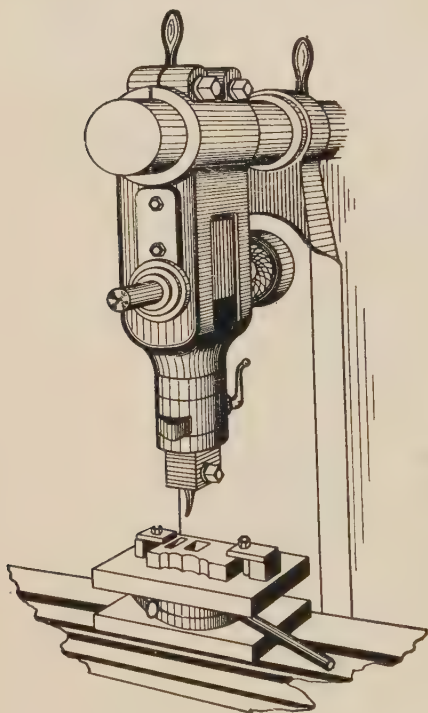


Fig. 318. Die Shaper

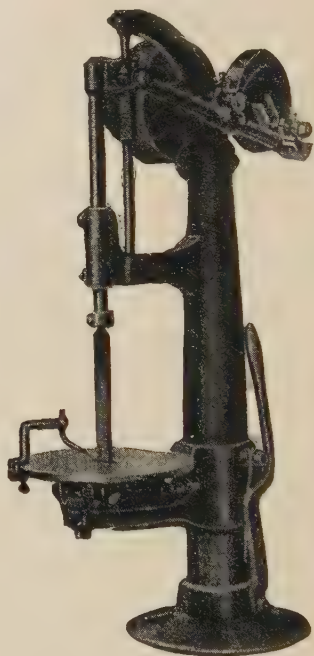


Fig. 319. Die Filing Machine for Filing and Lapping Dies, Gages, etc.

small clearance angle where any rounding of the surfaces would not be allowable.

Shearing. Die blocks have their cutting edges beveled in order that the blank may be cut from the stock by a shearing cut. Shear is given the face of the die to reduce the power necessary to cut the blank from the stock, so that a thicker blank can be cut. The shear also reduces the strain on the punch and die.

The face of the die is sheared when the blank, or piece forced through, is the product to be saved. But if the piece surrounding the blank is to be saved, and the blank is of no use, the face of the die is left perfectly flat and the end of the punch is sheared.

The cutting face of the die may be sheared by milling or planing to

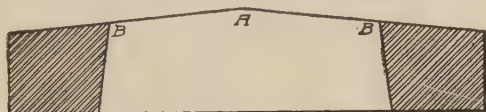


Fig. 320. Die for Punching Heavy Spring

the desired angle, depending on the thickness of the stock to be punched and also on the power of the press. A common method of shearing a die is shown in Fig. 320, which shows a section of a die used for punching a heavy spring. The end of the punch is left flat. The punching, commencing at the center *A*, is continued with a gradual shearing cut as the punch descends until it reaches the



Fig. 321. Forging Requiring Extra Amount of Power

ends *BB*, of the opening. The blank punched will be straight, but the stock will bend somewhat unless it is quite stiff, in which case it springs back to shape when the pressure is removed.

When the punching requires an amount of power in excess of the capacity of the press, as in the case of the forging shown in Fig. 321, it is necessary to trim the flash occasioned by the process

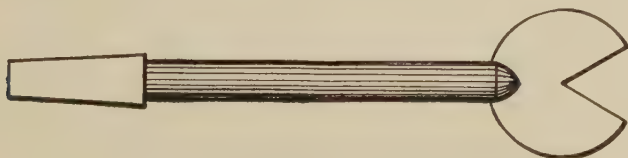


Fig. 322. Piece Forged and End Punched at Same Time

of drop-forging, and at the same time to punch the end to shape, as shown in Fig. 322. It is obvious that the material removed is not the valuable part, and, as it is necessary to use a light press,

the die may be given a shear as shown in Fig. 323, thus making it possible to do the punching on a press whose capacity would not be equal to the job if the die had been sheared as shown in Fig. 320.



Fig. 323. Shearing Die for Preceding Piece

In order to facilitate the operation of grinding the face of a die, it is frequently made with a raised boss around the hole as shown in Fig. 324.

Sectional Dies. In order that dies may be worked to shape more easily, they are sometimes made in two or more pieces which are fastened together when in use. The plain die, Fig. 325, is made in two pieces, which are held in their relative positions by the dowel pin at each end, shown at *A* and *B*; when in the die holder, they are held together in such a manner that they cannot spread.

Dies of this form should have the surfaces that go together finished true; the pieces should then be clamped together, and the dowel pin holes drilled and reamed. They should then be taken apart and any burrs caused by drilling and reaming removed. The pins should now be inserted, and the top and bottom of the die planed. The outlines of the piece to be punched are next laid out, and the round hole at one end drilled, after which it should be reamed from the back with a taper reamer to give clearance. The die is

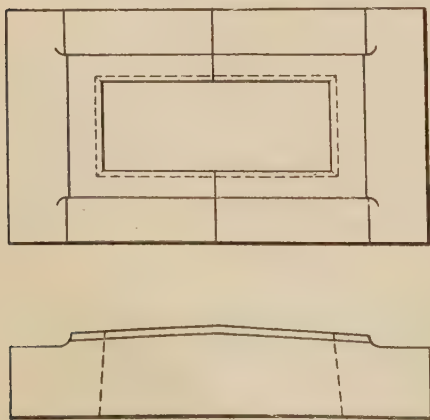


Fig. 324. Boss around Hole for Grinding

then taken apart, and the opening cut out on the planer or shaper, the sections of the die being held at the proper angle to give the desired amount of clearance. After the two pieces have

been put together, the opening may be finished to the templet with a file and scraper.

To hold the die together securely, it is necessary to use a die holder of the form shown in Fig. 326. The die is represented in

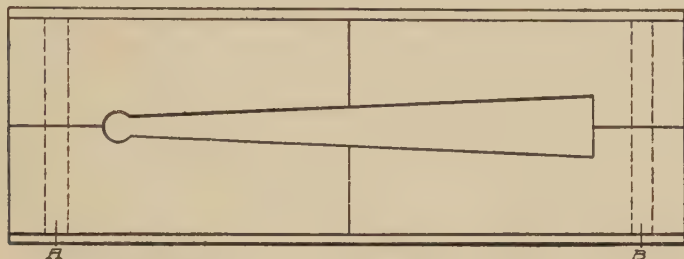


Fig. 325. Two-Piece Die

place in the holder, which is held in the bolster, this being in turn attached to the bed of the press. When the die is finished to the templet, and the proper clearance given, make sure that the walls

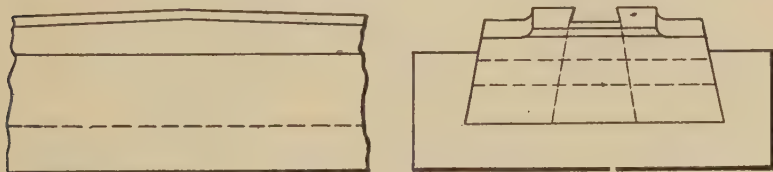


Fig. 326. Die Holder

of the opening are straight (not crowning), although it is not always considered advisable to carry the clearance to the edge, as the size of the opening would then increase every time the die was sharpened. In such cases the clearance extends from the bottom to within a short distance (about $\frac{1}{8}$ inch) of the cutting surface, as shown in the sectional view, Fig. 327. In this figure the clearance is exaggerated to illustrate the idea more plainly.

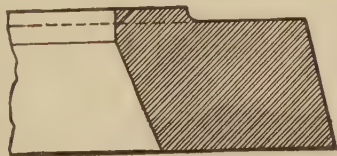


Fig. 327. Clearance of Dies Exaggerated

The walls of the upper part of the opening are at right angles to the base of the die; but they must be straight (not crowning) because if the opening is wide enough to allow the punch to pass through the crowned part, the

stock would, if thin, be likely to leave the blank with ragged edges which would extend up on the sides of the punch and have a tendency to burst the die.

Hardening Dies. *Applied to Ordinary Shapes.* Before hardening, the stripper and guide screw holes should be drilled and tapped, and the hole drilled for the gage pin or stop. If the name of the part to be punched, or the shelf number of the die is to be stamped, it should be done now. After all screw holes, stop-pin holes, etc., are filled with fire clay mixed with water to the consistency of dough, the die is ready for hardening. Extreme

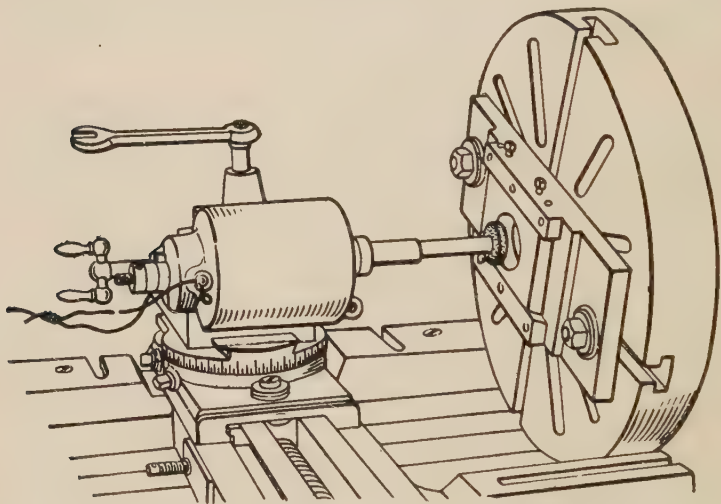


Fig. 328. Grinding Round Opening in Die

care should be exercised in the heating; the heat must be no greater than is absolutely necessary, and it should be uniform throughout—the corners of the die must be no hotter than the middle of the piece, and the outside surface must be of the same temperature as the interior of the steel. The water in the bath should be slightly warmed to prevent any tendency to crack. The die should be lowered into the bath and swung back and forth gently so that the bath may pass through the opening and harden the walls. As soon as the singing ceases, the die should be removed and plunged into a tank of oil and allowed to remain until cold, when it is brightened and the temper drawn. If more

than a few minutes are to intervene between the time the die becomes cold and the time for commencing to draw the temper, the die should be held over a fire or placed where it can be heated, to remove the internal strains which have a tendency to crack the piece.

When there is a heavy body of metal around the openings in a die, and a light partition between the openings, there is danger of cracking during the hardening. In such cases a little oil applied to the light portion when red hot and just before quenching, especially at the point where it connects with the heavier portion, thus prevents too rapid cooling of the parts, and so does away with the danger of cracking. The oil may be applied by means of a piece of cloth, which may be attached to a wire; in this way the oil reaches the desired spot and no other. The oil having been applied, the die may be cooled in the bath in the usual manner.

Applied to Special Shapes. When a die of such a shape that it is likely to give trouble, is to be hardened, much more satisfactory results will follow if the pack-hardening process is used. Run the dies from one to five hours in the fire after they are red hot; then dip them in raw linseed oil and swing them back and forth to force the oil through the opening. Dies having openings that are perfect circles may be left a trifle small until after hardening, when they are ground to exact size as shown in Fig. 328. Here the die is held in a chuck and the grinder is motor driven.

Tempering. A very common method of drawing the temper of dies and similar pieces, is to heat a piece of iron to a red heat and place the hardened piece on it, leaving the face of the piece uppermost. Experience shows, however, that this method of treatment is too harsh for hardened steel, especially if the job is in the hands of one not thoroughly experienced, for it subjects one side of the piece to an intense heat while the opposite side is exposed to the cooling effects of the air. If an open fire is used, a plate may be set on the fire, and the die placed on the plate before it is hot; now the temperature of the plate may be raised gradually, the die being turned occasionally. In this manner, the temper can be drawn to the desired degree with safety. When such a fire is not available, two plates may be used, one heating while the other is in use. The first one should not be very hot, the next somewhat hotter, and so on until the die is drawn to the desired color.

Punches. The punch is used to force the metal through the die, thus producing pieces of the desired shape.

In the case of small plain dies, the punch is generally made of the form shown in Fig. 329. The end *A* is of the same outline as the opening in the die; the shoulder *B* which bears against the



Fig. 329. Plain Punch

holder, takes the thrust when the punch is working; the shank *C* fits the hole in the punch holder or in the ram of the press. It is customary

in most shops in this country to make the die to a drawing or a templet, and then to harden it, after which the punch is fitted to it.

Laying Out. The templet may be used in laying out the punch for a plain die. If the shape of the opening in the die is the same on each side, Fig. 330, and the die does not change shape in hardening, either side of the templet may be used next to the face of punch; but if the outline is of the form shown in Fig. 331, it will be necessary to exercise care to see that the proper side is used, because the side of the templet placed against the face of the punch

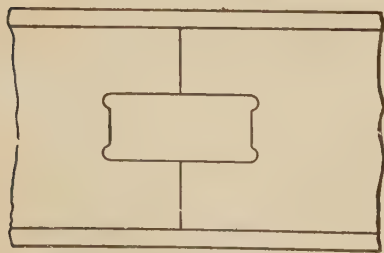


Fig. 330. Typical Die of Same Shape at Both Ends

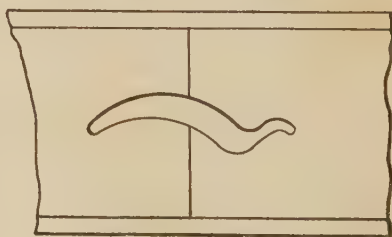


Fig. 331. Die of Odd Form

when laying it out will be opposite to the one placed against the face of the die when laying that out.

In order to obviate this trouble, many tool-makers lay out the face of the punch from the opening in the die before beveling the face for shear. In order to hold the punch and the die together so that there will be no danger of the punch slipping while the shape is being transferred, a die clamp of the form shown in Fig. 332 should be used.

Machining to Shape. The punch blank should be faced on both ends, and the shank turned to size. The end which is to fit in the opening in the die should be finished with a smooth, flat surface, and colored with blue vitriol. After coloring, it may be clamped to the face of the die by means of the die clamp, and the outline of the punch marked on the face by scribing through the opening in the die. This outline should be accurately marked with a sharp-pointed prickpunch, as the scribed line is likely to become obliterated by the various operations of machining the punch to shape.

Milling or Planing. After the outline has been carefully prickpunched, the punch is ready to be milled or planed to shape, leaving enough stock at all points to shear into the die. If the punch is milled to shape, the irregular surfaces may be produced by means of a fly cutter, Fig. 333. If it is planed, it may be held in a pair of centers, as shown in Fig. 334, in a shaper. If the die has been left soft to permit laying off the punch, it should now be beveled for shear, and hardened.

Shearing-In. The punch should be machined close to the lines, and then placed over the hardened die and forced into it a little, about $\frac{1}{16}$ inch. This is termed shearing-in, and is a customary process in this country.

Filing. After the punch has been sheared-in for a short distance, it may be removed and worked to size by means of chisel, file, and scraper to the witness mark, as the portion sheared-in is termed. The operation of shearing-in may be repeated until the punch enters the entire length.

Fit of Punch in Die. If the material to be punched is thin or soft, it is necessary to make the punch a closer fit in the die than if the stock is heavy or very stiff. Thin stock requires a punch nicely fitted to the die in order to avoid ragged edges on the punched blank. When punching brass stock $\frac{1}{8}$ inch in thickness, the punch

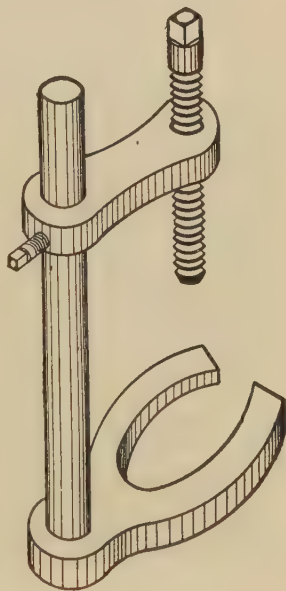


Fig. 332. Die Clamp

should be .0075 inch smaller than the die, the usual difference being 6 per cent of the thickness of the stock for brass, and 7 per cent for steel. If the stock is very stiff, a greater difference should be allowed, the exact amount depending on the nature of the material to be used and the character of the tool.

After the punch has been fitted to the die, the cutting end should be faced off to insure a good working surface and sharp edges. Any distinguishing names or marks necessary, should be stamped on it, after which it is ready for hardening.

Hardening. Punches are hardened by heating them in an oven furnace or in a clear charcoal fire, to a low red, and cooling

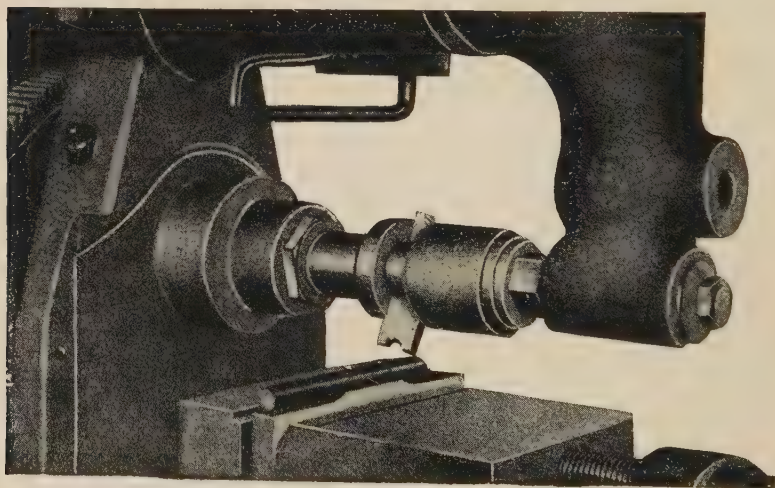


Fig. 333. Shaping the Punch with Fly Cutter

in water or brine, preferably the latter. Punches whose form insures strength, need be hardened only on the end; the hardening should not extend quite back to the shoulder or shank. Small, slender punches are sometimes hardened the entire length, especially if they are to punch stock nearly as thick as the diameter of the tool itself, for otherwise they would become upset when used.

It is generally considered good practice to have the punch softer than the die; on this account it is usually drawn to a color that insures this result. If a die is drawn to a straw color, the punch is drawn until it assumes a distinct purple, or even a blue color.

The punch is sometimes left soft—not hardened at all; when this is done, it can be upset, and refitted when worn. As this would

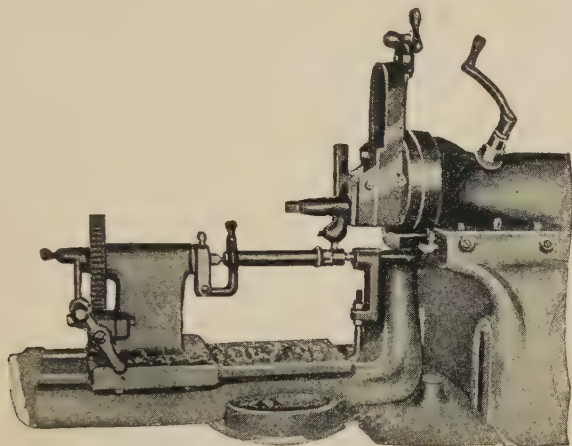


Fig. 334. Shaping Punch in a Shaper

not work satisfactorily in many cases, it can be recommended only when a soft punch is advisable.

Special Problems in Punching. *Punching Hole in Piece Machined to Shape.* It is occasionally necessary to punch a hole in a piece of work that has been machined to some given shape. The piece is placed on the face of the die against locating points, or in an opening in a gage plate, the opening being of the same outline as the piece of work. In Fig. 335 is shown a blank intended for a gunsight leaf; *A* shows the blank before the rectangular hole is punched, while *B* represents the leaf after punching. The hole is punched somewhat smaller than finished size, enough stock being left to work to size with broaches.

When punching work of this description, it is necessary to leave the face of the die flat; the punch is sheared as shown in Fig. 336. The piece punched from the leaf is of no value in this case; consequently, the face of the punch is

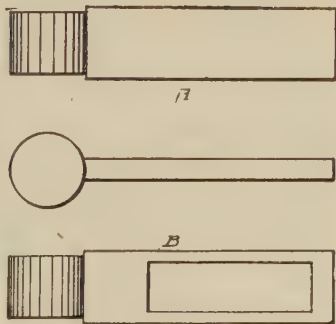


Fig. 335. Gunsight Leaf Punching

beveled, and the face of the die is left flat in order that the sight leaf may be straight after punching.

Use of Stripper. When a die and punch are to be used for an operation similar to the one just described, it is necessary to make a stripper of a form that allows the pieces to be easily placed in position and removed. As the piece which is punched is likely to increase in width from the operation, it is advisable to have stops or a guide on one side only, in order that the piece be readily removed after the hole is made. Fig. 337 shows the die with stripper and guide attached. The stripper is raised sufficiently from the die

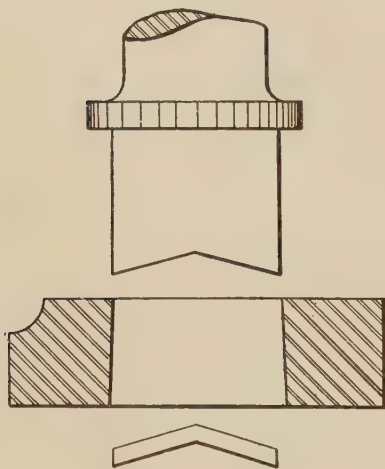


Fig. 336. Sheared Punch

to allow the work to be readily inserted. A gage pin is furnished for the end of the piece, to determine the position of the slot in relation to the end. On one side is a guide against which the piece rests to bring the slot into a central position, the piece being held by means of a screwdriver, a thin piece of steel, or a piece of wood.

When the size of a piece to be punched does not allow the use of a stripper attached to the die, as in the previous example, the stripper may be attached to the punch, Fig. 338. It is made in such a manner that the stripper plate, descending with the punch, comes in contact with the piece being operated on and remains stationary; between the stripper plate and the punch holder are coil springs which are compressed. The punch passes through the piece and returns, and the stripper, being forced downward by the action of the springs, forces the blank from the punch. The gage plate which is securely fastened to the die by screws and dowel pins, as shown, has an opening of the same general outline as the blank, but somewhat larger, in order that the blank may be easily put in place and removed.

Punching Incomplete Holes. It is sometimes necessary to punch a hole incompletely, leaving the portion punched out attached at one

end, as shown in Fig. 339. If several holes are to be made in the piece, the punches may all be attached to one holder, and all let into one die block. This method of punching is resorted to when

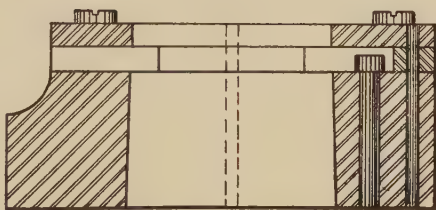
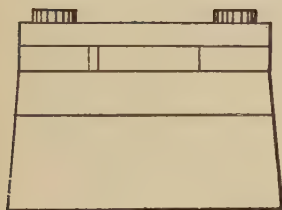
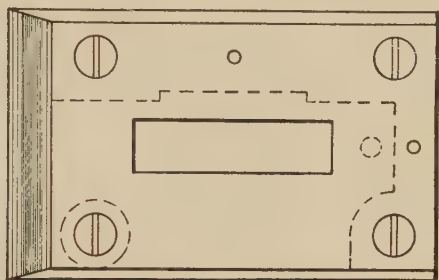


Fig. 337. Die with Stripper and Guide

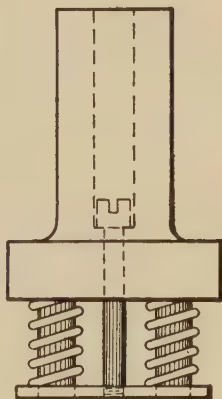
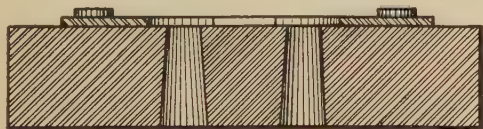
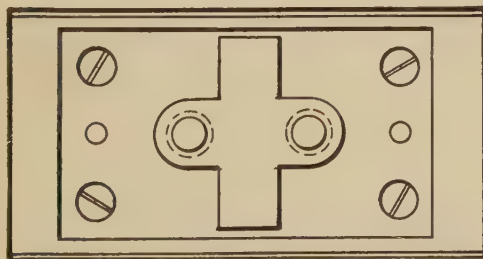
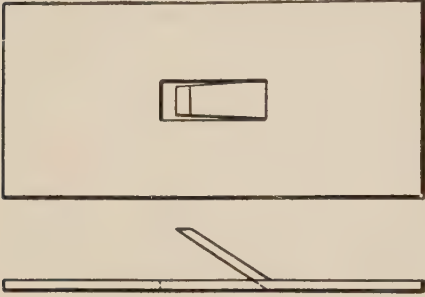


Fig. 338. Punch and Die with Stripper Attached

manufacturing skates, as the portion bent down from the plate is shaped by subsequent operations to provide a bearing for the toe clamps.

Piercing and Curling. A very satisfactory form of piercing and curling die is illustrated in Fig. 340. The various stages of the operation of punching, piercing, and curling are shown at *a*, *b*, and *c*. At *a* the punch is starting to 'pierce the sheet;



b shows the punch having pierced the stock and starting to curl the loop; *c* shows the loop curled up against the sheet. If it is considered necessary, the punch may be set to go lower and curl the loop inside of itself, as shown at *d*; or the end of the punch

may be flatted somewhat, as shown at *e*, and a loop formed as shown at *f*. This die may be made multiple, and any number of loops (within the capacity of the press) made and formed at one

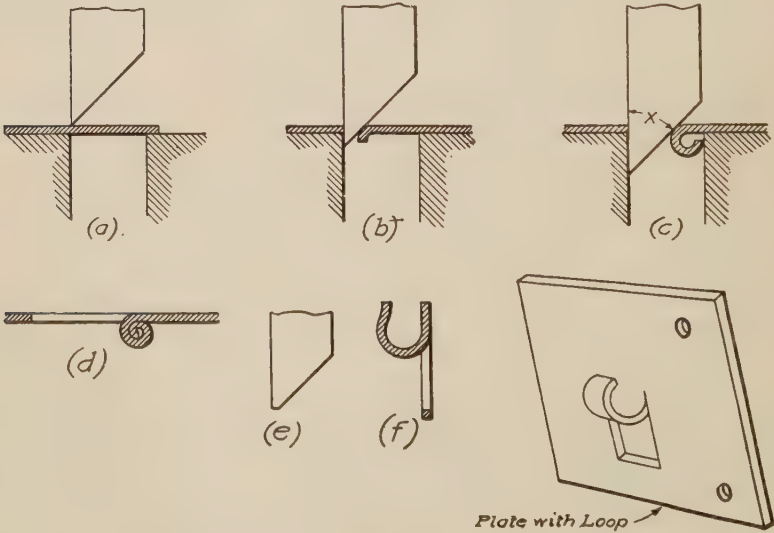


Fig. 340. Piercing and Curling Die

time; or piercing and cutting-off punches may be combined, screw holes or other holes punched, and strips of any desired length cut off, at one operation. A stripper plate, attached to either the

punch or the die, should be provided to strip the work from the punch. If attached to the die, the stripper must be high enough above the face to permit of easy removal of the work from the openings of the die.

Gang Dies. The gang die is designed to punch in one operation the blank itself and also any holes to be made in the blank. Two operations would be necessary if a punch and die of the form shown in Fig. 338 were used.

A common design of a gang die is shown in Fig. 341, which represents a die for the piece operated on in Fig. 338. The stock is fed from right to left. The sheet rests against the guide *C*, and is so located that the end slightly overlaps the front edge of the opening *E*. The two holes *F* and *F'* are punched, and the end of the sheet is trimmed by the punch *A* to furnish a locating point to go against the stop *D*. At each stroke of the press a blank is produced and the two holes are punched. For the next

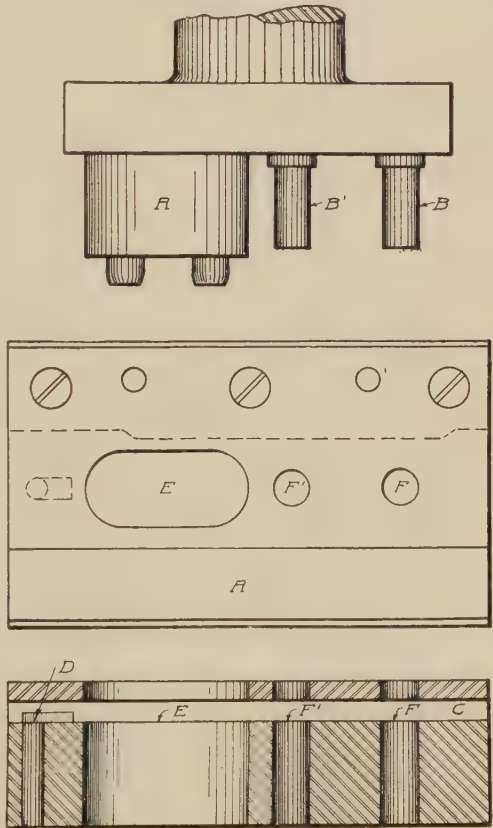


Fig. 341. Gang Die

blank the gage pin *D* should be located about .010 inch farther to the left than the proper location for punching. The center pins, as they enter the holes, draw the stock back to the proper location. It is obvious that the punch *A* must be a trifle longer than the punches *B'* and *B*; were the small punches longer

than A or even of the same length, they would hold the stock in such a manner that the centering pins could not locate it, and, moreover, the centering pins, striking on one edge of the hole, would spoil the blank punched, and probably cause the pins to break. The centering pins must not be a tight fit in the holes, or the punched blank will stick to the pins and return with the punch. By carefully fitting the pins to a punched hole, punching

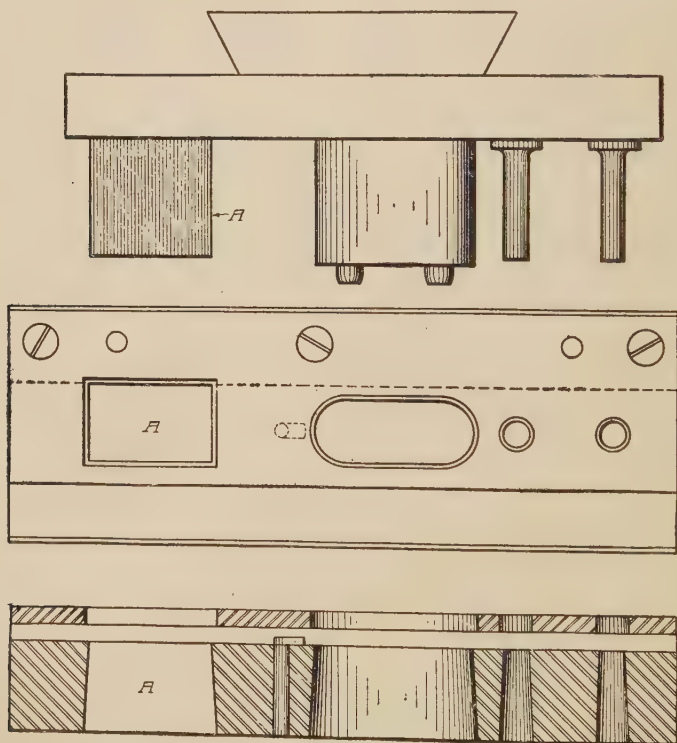


Fig. 342. Punch and Die Which Cut Away Scrap

within a very small limit of variation can be insured; in fact, for most classes of work, it is possible to punch near enough to standards for all practical purposes.

When a gang die of the design shown in Fig. 341 is used to punch a strip wider than is necessary to get out two punchings, it will be readily seen that the scrap left between must be removed by some means. This is frequently done by a large lever shear

or a pair of power shears, but that is a costly operation where many pieces are punched at a time. To avoid this extra cost, dies are made with an extra opening, and a punch working into this cuts away the surplus stock or scrap, leaving the edge of the sheet straight and in condition to rest against the guide. In Fig. 342, the opening *A* is the trimming die; the punch working in this cuts away the scrap, leaving the edge of the sheet straight.

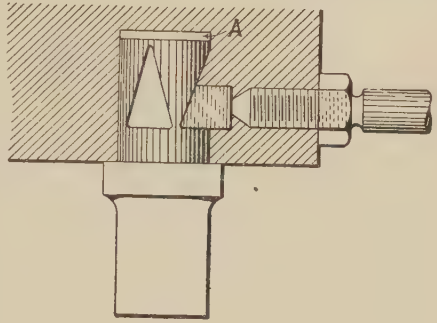


Fig. 343. Punch Holder to Prevent Loosening

At times, punches set in a holder, Figs. 341 and 342 have a tendency to loosen and draw out of the bearing. A method for preventing this is shown in Fig. 343, an angled block pressing against the punch shank *A*.

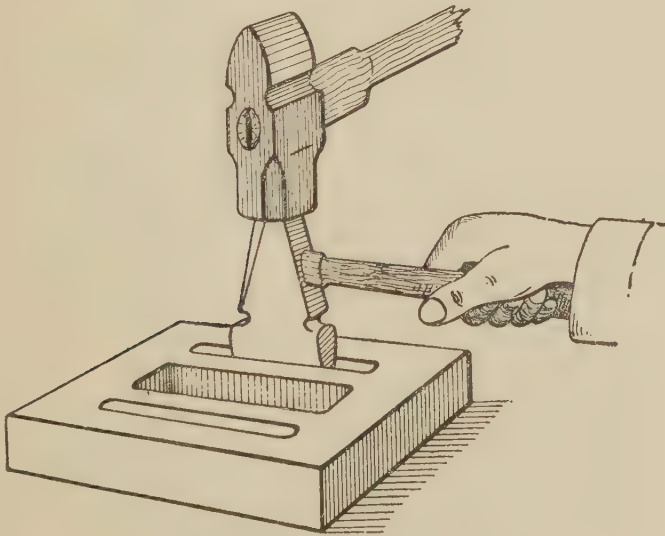


Fig. 344. Repairing Worn-Out Die with Fuller

When a die becomes worn through use so that the opening is large, it may be placed in the fire, brought to a forging heat, and the opening closed with a "fuller", Fig. 344. After being annealed,

the die can be worked out to size and hardened. In this way dies can be worked over several times. Fig. 345 shows a die with the core sawed out by means of a power saw.

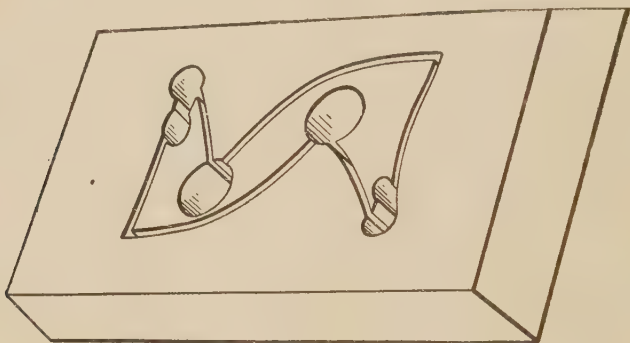


Fig. 345. Die with Core Sawed Out

Punches with Guide Bushings. A great amount of trouble is experienced in some shops when attempting to use small piercing punches to produce holes in stock as thick as the diameter of the

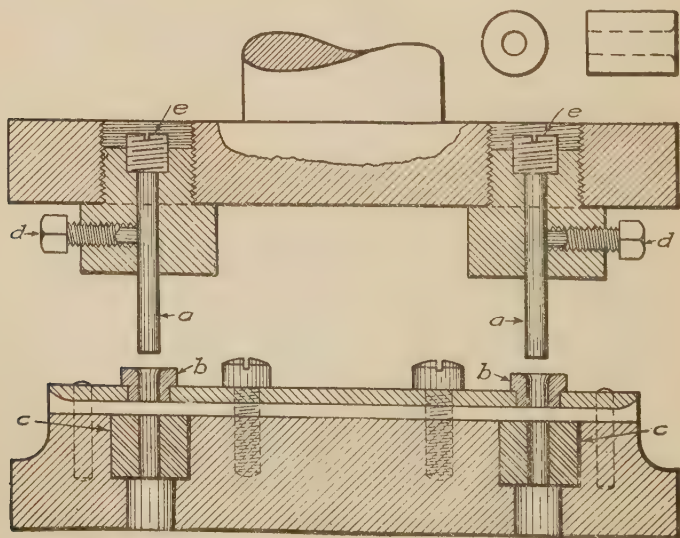


Fig. 346. Die with Guide Bushings

punch, or thicker. This difficulty can be obviated by using guide bushings in the stripper plate to support the punches and guide them to the opening in the die. The bushings should be made

from tool steel, hardened, the holes ground and lapped to an exact fit for the punches; or, in the case of very small punches, where grinding is out of the question, the hole may be lapped to size, and the outside ground to size to force it into the hole in the stripper plate.

The guide bushings must be in exact alignment with the openings in the die. Fig. 346 shows a form of die provided with guide bushings *bb*, for the punches *aa*. The dies *cc* are made from tool steel, hardened, and forced into a machine-steel die block. The punches are made from drill rod and are held in place by binding screws *dd* and adjusting butt screws *ee*. Between the binding screws *d* and the punch, at the end that bears against the punch, is a piece of wire of semicircular shape. This allows the punch to be set down as the punching end is ground away.

In the case of gang punches and dies, used in the production of perforated sheet-metal work, which have sometimes several hundred piercing punches working into one die, it is customary to provide each punch with a guide bushing.

Punches with Tapered Section for Spreading.

Trouble is experienced at times with blanking and piercing punches because the metal clings to the punch and pulls the end off in the operation of stripping. This is especially the case when a clinging metal is being worked. The trouble can be avoided by making the punch of the design shown in Fig. 347, where the portion marked *a* is straight and the desired fit in the die. The portion *b* is tapered and smaller at its junction with *a*. When the die is set up in the press, *a* enters the die nearly its entire length; the tapered portion *b*, entering the stock, spreads it, thus enlarging the opening, and so preventing it from binding the punch during the process of stripping. It is of course necessary, when setting a punch of this design in the press, to make sure that the tapered portion does not enter the opening in the die.

Multiple Die. If the shape of the pieces to be punched allows it, it is sometimes advisable to make several openings in the die of the same outline so arranged that as many pieces may be punched at a time as there are openings in the die block. This will effect

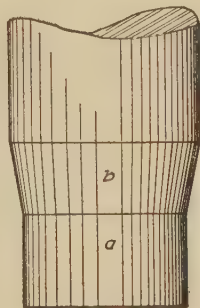


Fig. 347. Punch Designed for Clinging Metal

a great saving where work is punched in large quantities. In the manufacture of perforated sheet-metal work, it is customary to make dies having as many as five hundred punches working into one die block at a time; but as this is an unusual application of this principle, it will not be considered.

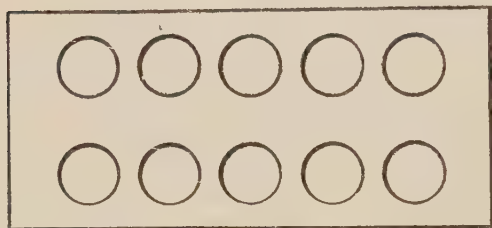


Fig. 348. Sheet-Metal Blank

If it is necessary to punch ten holes in the piece shown in Fig. 348, a die can be made having this number of openings. Then, by making a punch holder having

an equal number of punches properly located, all the holes can be punched at one stroke of the press.

While in the case just cited the piece of stock which had the holes punched in it is the product, the punchings being scrap, the same principle can be applied to punching blanks from a sheet of stock. The design shown in Fig. 349 is the product in a shop where many thousands of this piece are used monthly. The die produces a dozen or more blanks at each stroke of the press, but for convenience in illustrating the die and punches, but four openings in the die, with a corresponding number of punches are shown, Fig. 350.



Fig. 349. Simple Stamping. Twelve Produced at a Stroke

If a die were made with the openings near enough together to punch the stock, Fig. 351, there would be so little stock between the openings that the die would not stand up when used; for this reason the openings are located in such a manner that every other opening is omitted. When the punch descends, four blanks are punched, and, the stock is moved until the first opening strikes the gage pin, Fig. 350. This leaves the stock in position

to punch between the openings already made. The next time the stock is moved until the gage pin strikes the wall of the last opening to the right.

Bending Die. In order to bend metals to various forms, dies are made for use in punching presses, drop hammers, and various

other machines. A simple form of bending die is shown in Fig. 352. The shape of the upper and lower parts of the die is such that when the upper part is brought down on the blank *B* (shown by the dotted

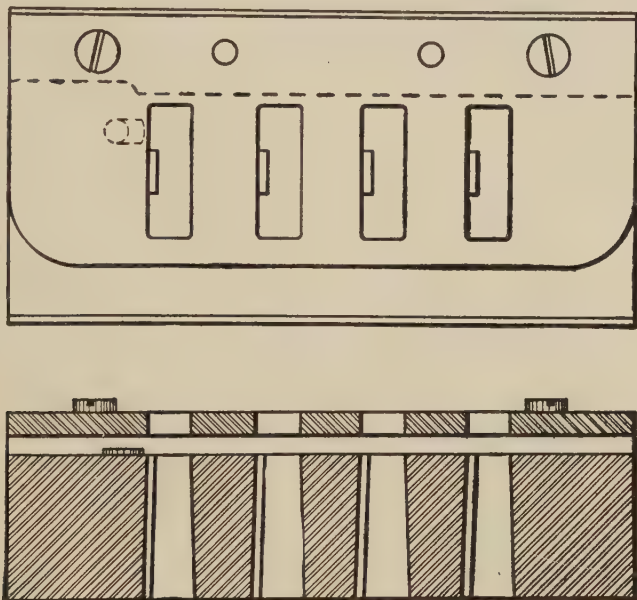


Fig. 350. Gang Punch and Die for Simple Punching

lines) that will be bent to the required shape. The shoulder *A* forms a locating stop, against which the blank rests before bending.

Dies for extremely soft metals may be made of the exact shape of the model, or the shape the piece should be when finished; but if the piece is of stiff material which bends with difficulty, it will be necessary to make the die of a form that will give the article *more* bend than is required, as the piece will spring back somewhat as soon as released by the return of the upper part.

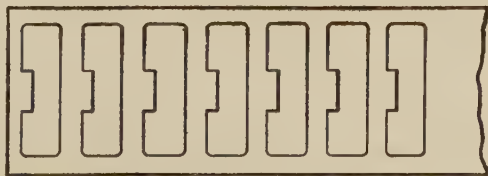


Fig. 351. Punchings Too Close Together

The bending of articles of certain shapes requires tools so designed that certain portions of the piece will bend before others. Any attempt to make the tools solid, and thus to do the bending

of the various portions at once, would result in stretching the stock. As a rule it is not advisable to stretch stock, and dies are constructed

to do away with this trouble.

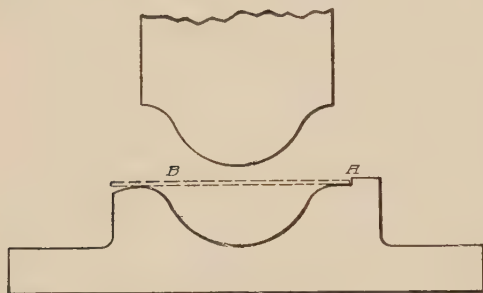


Fig. 352. Simple Bending Die

to do away with this trouble. *Bending Die for Right Angles.* Under certain conditions a bending die which has a horizontal surface for the work to rest on and a vertical-sided punch does not work in a satisfactory manner—this is especially true when the stock is stiff. In that case, a die of the design shown in Fig. 353 works well, as the angle may be made other than 90 degrees to allow for the spring of the metal.

This design of die may be used for angles other than right angles. It is especially satisfactory for bending springs and other pieces made from a stiff stock that is liable to spring back somewhat after bending, as the lower block may be made with an angle greater

than 90 degrees to allow for this factor.

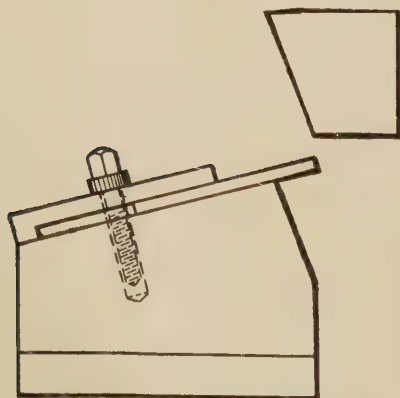


Fig. 353. Bending Die for Right Angles

Bending Die for Light Work.

For comparatively light work, the form of bending die shown in Fig. 354 is very satisfactory, and may be used for a variety of shapes and angles. The die block *a* is drilled and reamed to receive the shouldered portion *b*. The rectangular groove, to receive the pad, is milled or planed, and the pad is fitted and forced in. The proper angle

or shape is then milled in the block *a* and pad *b*. The surfaces are carefully finished and the pad forced out and drawfiled until it slides nicely in the groove. The spring *c* forces the pad against the washer *d*. Gage plates are provided to locate accurately the pieces to be bent.

Fig. 355 shows a die, the upper part of which has the portion *a* so constructed that it engages the stock first and forces it down into the impression in the lower portion. The resistance of the coil spring is then overcome, and *a* is forced up into the opening provided for it. The arms *cc* bend the ends of the piece. After bending, the article is of the form shown at *b*.

Compound Bending Die. In Fig. 356 is shown a form of die used in bending bow spring and looped wire for armature connections or other looped wire-work. The work is placed in the die, and the punch, as it descends, bends the wire to the shape of the die. The spring just back of the punch is compressed; this allows the punch holder to descend and force the side benders *BB* toward the punch by means of the wedge pins *AA*, and thus forms the piece into a circle. Fig. 357 shows the punch when down. It is obvious that it is necessary to make the shape of the punch and die different. The lower die must have its bending surface a curve of a radius equal to the radius of the punch plus the thickness of the material.

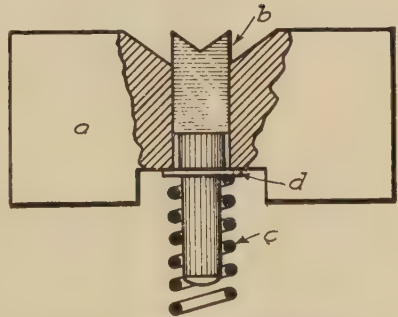
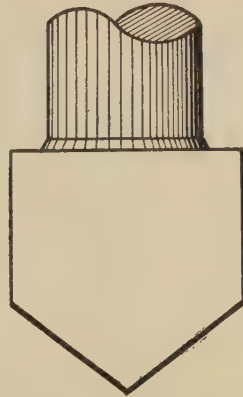


Fig. 354. Bending Die for Light Work

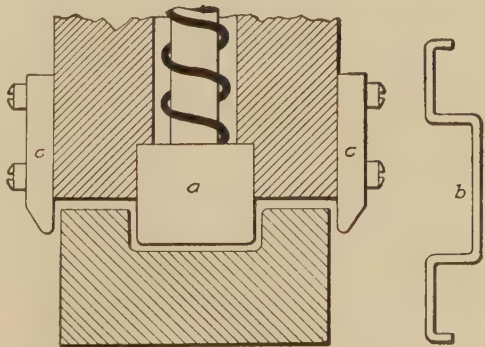


Fig. 355. Spring Bending Die and Finished Piece

Forming Die. This type of die is familiarly known as a *drawing die*. The most common example of the forming die is that used for

drawing a flat, circular blank, shown at *A*, Fig. 358, into a cup-shaped piece, shown at *B*. This operation can be done in an ordinary

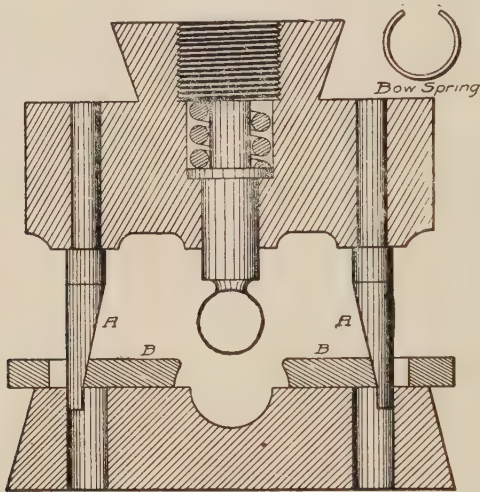


Fig. 356. Compound Bending Die

punching press by means of a forming die of the shape known as a *push-through die*, so called from the fact that the piece is formed to shape and pushed through the die at one operation. This form of die is shown in Fig. 359. The face of the die is cut to receive the blank; this depression is known as the “set edge”. The opening

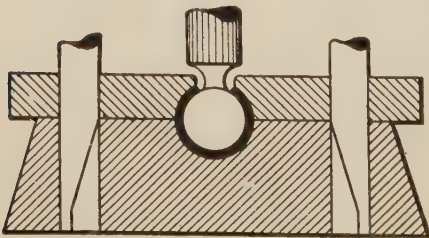


Fig. 357. Punch at Bottom

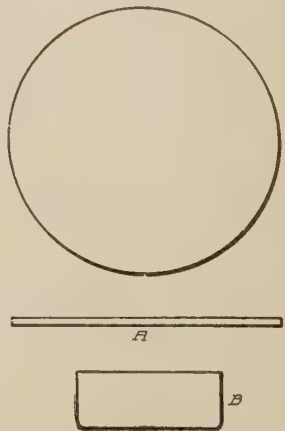


Fig. 358. Flat Blank Drawn into Cup Shape

in the die is given a “draw” of from $\frac{1}{4}$ to $\frac{1}{2}$ of a degree, making it larger at the top; the upper edge is rounded over and left very

smooth, and the bottom edge is made very sharp, in order that the piece may not be carried back with the punch as it returns.

This form of die is left as hard as possible, and the walls of the opening are made as smooth as they can be polished. It is sometimes advisable to finish the walls with a lateral rather than a circular finish.

Hardening Drawing and Redrawing Dies. Drawing and redrawing dies having holes which pass entirely through them, as shown in Fig. 360, give considerable trouble when hardened unless proper methods of treatment are used. The principal difficulties experienced are alteration in the size of the hole, and soft spots in the walls of the holes.

As there is no need for the exterior of the die being hard, the whole attention of the hardener should be given to getting the walls of the hole as hard as possible, as this portion is subjected to

considerable strain and to excessive abrasive action, and soft portions render the die useless. This is especially true of dies used for such work as redrawing cartridge shells and similar pieces.

In order to harden the walls of the hole, and yet leave the circumference of the die soft, it is necessary to make a fixture to cover the portions desired soft. Such a fixture is shown in Fig. 360. It may be made from a piece of cast iron, the portion *A* being a little, say 1 inch larger than the diameter of the die. The opening to receive the die should be $\frac{1}{16}$ inch larger than the die. The balance of the hole should be somewhat larger than the hole in the die, say $\frac{1}{4}$ inch. A cover may be made of the same material, and it should be a loose fit on the holder. The hole in the cover should be $\frac{1}{4}$ inch or more larger than the hole in the die and beveled as shown.

When the die is heated to a uniform red, it is placed in the fixture, the cover put on, and the whole held under a water pipe, or faucet, Fig. 362, while the water is allowed to flow through the

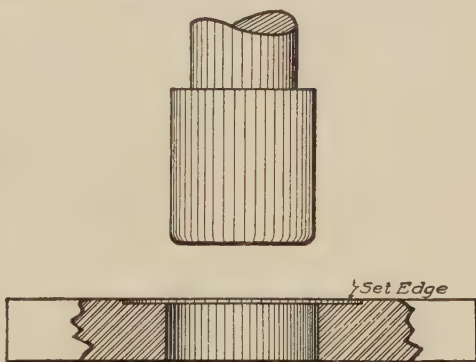


Fig. 359. Push-Through Die for Cup-Shaped Work

hole as shown. A mistake sometimes made consists in placing the fixture in a bath and then attempting to force the water through

the hole; unsatisfactory results always follow if this is done, for the water cannot flow through the hole, pockets of steam form which prevent hardening, and soft spots result. The fixture should *not* be immersed in water, but should be held so that the water can pass unretarded through the hole and carry the steam with it. The water supply should be sufficient to fill the hole and should pass through under a fair head, but not too swiftly.

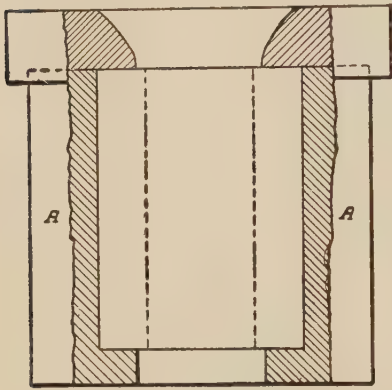


Fig. 360. / Fixture for Covering Soft Portion of Die

This method, when properly executed, gives excellent results. As a rule, dies of this kind are left dead hard, the temper not being drawn at all.

Reversed Die. The die shown in Fig. 362, known as a reversed die, is extensively used in many shops for heavy punching on such work as washers, ball seats, etc. Under many conditions, it works much better than a gang die, and it is simpler to make than a compound die.

The punch *A* is made the size of the diameter of the washer to be produced, and is hollow to receive the punch *B* which produces the hole. The scrap from *B* passes up through the punch *A* and through the outlet shown.

The washer blank remains in the die *C* until forced out by the ejector *D*, which is automatically operated by the press.

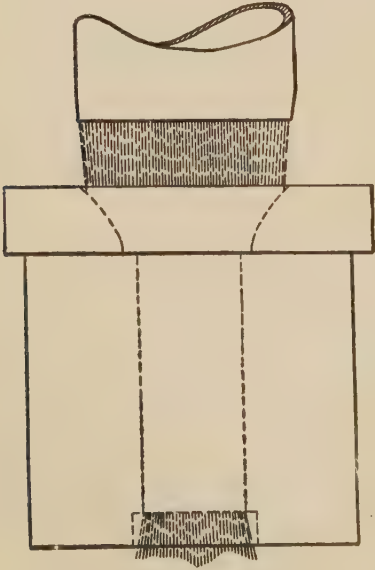


Fig. 361. Method of Hardening a Redrawing Die

Compound Dies. In Fig. 363 is shown a die used in producing a washer and punching a hole in it at one operation, thus insuring a blank with a hole that is exactly central. The work from a die of this description is better than that done by the gang die. It is especially adapted for thin sheet metal, paper, and mica parts.

The upper die *A* receives the lower punch *B*, while the lower opening *C* receives the upper punch *D*. The stripper *E* forces the

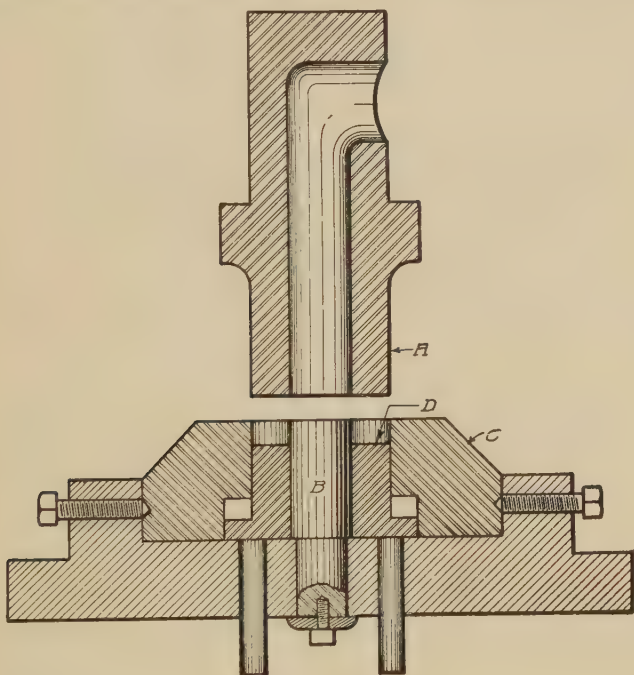


Fig. 362. Reversed Die

blank out of the die; while the stripper *F* forces the sheet off the punch *B*.

The die shown is for punching a round washer, but the tool may be made for producing pieces of complicated and irregular form. It proves especially valuable when used in connection with a sub-press.

Triple Dies. When it is necessary to punch three or more holes in a tubular or other shaped piece where this form of die can be used, a triple die effects a great saving, as the holes can be punched at one stroke of the press.

Fig. 364 shows a die used for punching three holes in a tube and is intended for use in any simple power press. The dies *AAA* are placed in a hollow stud which fits in the inside of the piece to be punched. The vertical punch is held in the punch holder as shown. The horizontal punches are operated by means of the inclined arms *CC*, working in the horizontal slides *BB*.

The horizontal punches in the illustration are made from drill rod of the desired size; but they may be of any desired form,

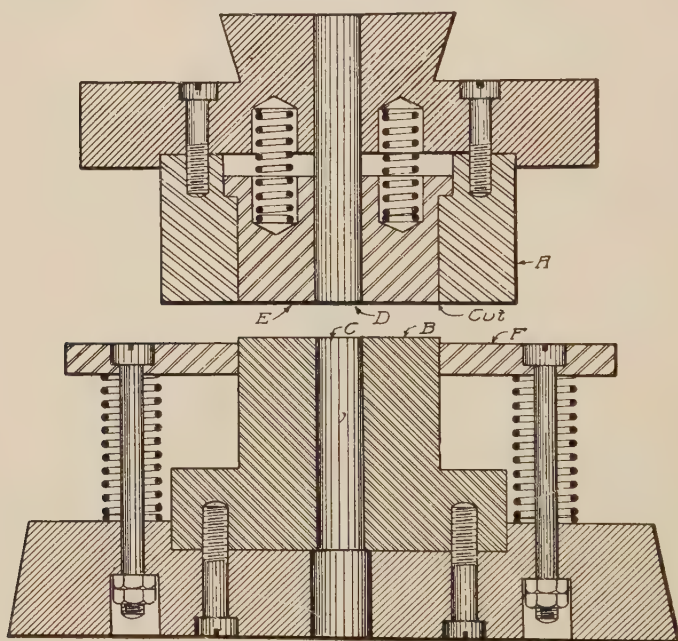


Fig. 363. Compound Die for Producing Washer at One Operation

the opening in the die being made to match. Where work is done in batches sufficiently large to warrant the expense of a triple die, its construction is to be recommended, as better results can be obtained than if one hole is punched at a time.

Follow Dies. The name follow die is given that form of die where the pieces are blanked and bent at one operation. In Fig. 365 is shown a punch and die used in producing the piece shown at the left. The two holes in one end and the opening at the opposite end are punched, and the piece bent to shape, at one passage through

the press. The bending, piercing, and cutting-off punches are all attached to the same holder as shown in the upper part of the cut.

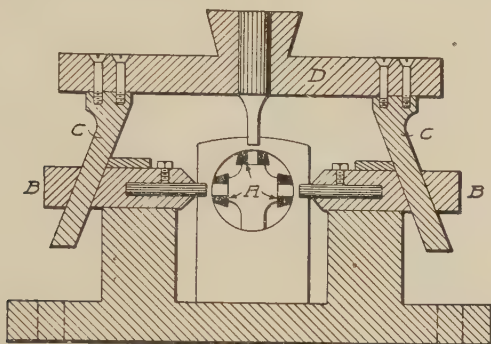


Fig. 364. Compound Die for Punching Three Holes in a Tube

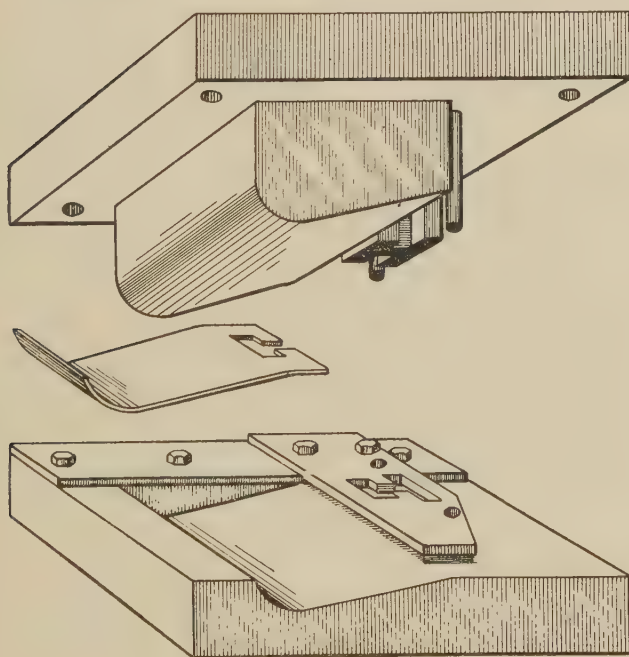


Fig. 365. Follow Die and Piece Produced

If the stock to be punched is soft, the bending portion of the punch and die may be made nearly the shape of the desired piece; if, on the contrary, the stock is stiff, they must be made of greater

angle to allow the piece to spring back after punching. The amount to be allowed cannot be stated, but must be determined by experiment.

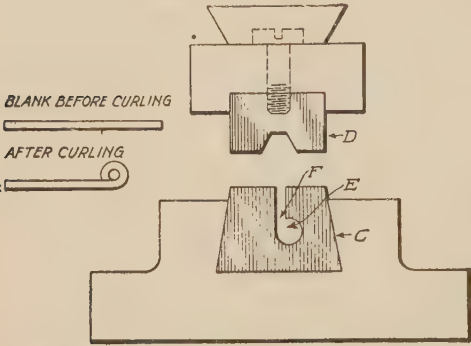


Fig. 366. Curling Die and Work. Before and after Operation

This test may be made while the die is soft, at which time the piercing or cutting-off portions must not be used. Dies of the type under consideration give best results if hardened by pack hardening.

Curling Dies. These dies are used in forming a loop such as is shown in Fig. 366 and marked

“After Curling”. The loops on hinges and similar pieces are examples of its work. The stock is first punched out as shown at the upper

left-hand corner, and the blanks are forced into a curling die of the design shown at *C*. The punch *D* has a V-shaped impression in its face, as shown.

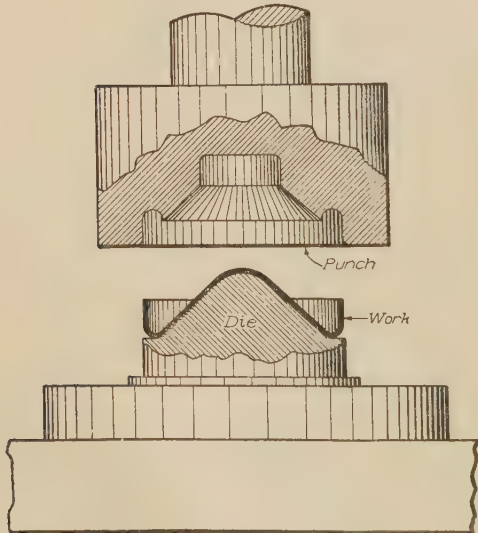


Fig. 367. Another Form of Curling Die

In making this die, the block *C* is machined to size. The hole *E* is drilled, reamed, and lapped to size; the lapping also produces a smooth hole, if a round, revolving lap of the right size is used. The slot *F* is then milled.

If the stock is comparatively soft or is easily bent, and if the die is to be used for but a few holes, it need not be hardened; if intended as permanent equipment, it must be hardened, preferably by the pack-hardening process.

Another form of curling die, Fig. 367, is used in curling a loop around the end of a circular shell or vessel. The stock entering the circular-shaped portion of the punch is made to conform to the size of the circle.

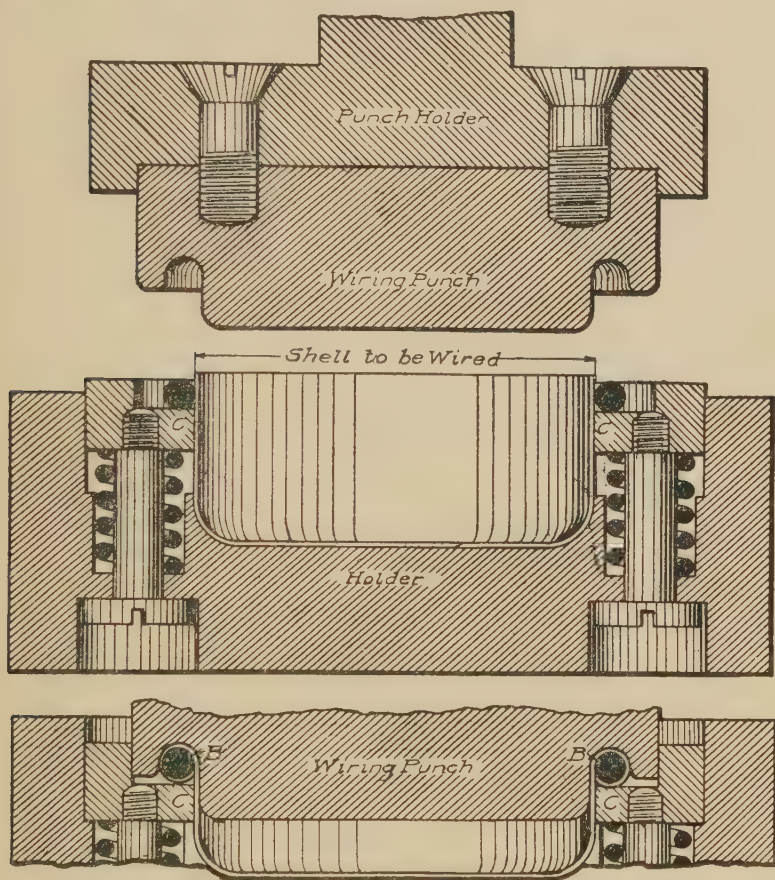


Fig. 368. Wiring Die

Wiring Dies. Wiring dies are similar in construction to curling dies. They are used to curl the upper edge of a vessel which is in the die, or holder, and lies on the top of a spring-supported ring *C*, Fig. 368.

As the punch descends, it depresses the ring *C* and curls the upper edge of the vessel around the wire ring, as shown at *B*.

Compound Punching and Bending Dies. In Fig. 369 are shown three views of a punch and die for cutting off and bending to shape at one operation a piece of special form; *D* is the finished piece. This form of die can be used for a variety of work, and it is recommended wherever the work is done in sufficient quantities to warrant the expense of the tool.

A is a view of both punch and die, showing also the punch holder and bolster; *B* shows the stripper used in knocking the finished piece from the bending punch; the cutting-off portion is seen in side elevation. The stock is fed through, and strikes the stop.

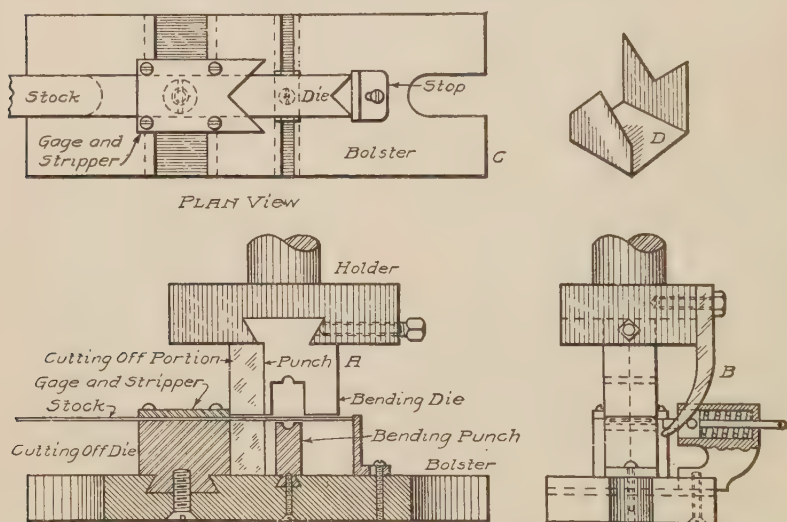


Fig. 369. Compound Punching and Bending Die

The cut-off is slightly longer than the arm of the bending die, in order that the stock may be cut off before the bender reaches it.

The stripper is a horizontal plunger actuated by a coil spring. This plunger has a pin through the back end to prevent it going too far, while another pin extends through the enlarged portion, against which the spring works. The inclined arm fastened to the punch holder will, when descending, force the plunger back and off the face of the bending punch. *C* is a top view of die.

There is sufficient space between the upper surface of the cutting-off die and the stripper so that the stock can pass over the plunger

stripper. The inclined arm which operates the plunger stripper pushes this out of the way before the descending punch reaches the stock.

After hardening, the cutting-off die and punch are drawn to a full straw color, and the bending part to a brown. When the cutting and bending parts are of complicated design, best results follow if they are pack hardened. The stock is purchased with the desired width, and the pieces punched and bent with no waste of stock.

Progressive Dies. Fig. 370 shows a die used to bend a caliper bow to a finished circle. This type of die may be used to produce pieces that are square in form, or of any one of a variety of shapes. It is generally necessary to resort to one or more preliminary bending

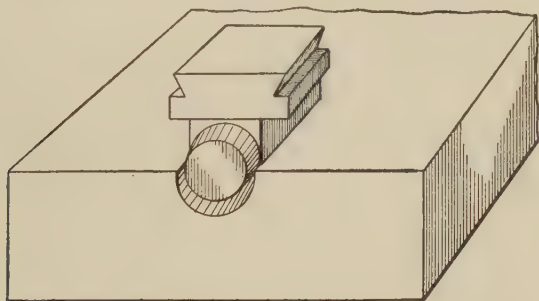


Fig. 370. Progressive Die for Bending Caliper Bows

operations to get the pieces to a form that makes it possible to bend them to finish form in the die shown. Since one or more dies are used before the final finishing die, and since one operation leads to another, dies of this class are grouped under the head of progressive dies.

The bow *a*, Fig. 371, is made by first punching a blank of the form shown at *b*. The ends of this blank are then bent separately, and shown at *c* and *d*. The piece is finally bent to the shape *a* by means of the die under consideration. It will be noticed that the forming portion of the punch projects out from the body and is provided with clearance space above it, in order that the ends of the piece may bend around it, and against one another if necessary. While the example of work given is simple, yet pieces of intricate shape can be produced by means of dies of this kind.

Another example of progressive dies and the work done with them is shown in Figs. 372 to 378, where Fig. 372 shows the die

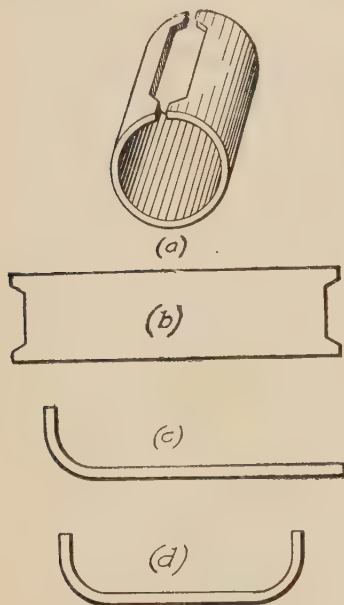


Fig. 371. Various Punchings in Making a Caliper Bow

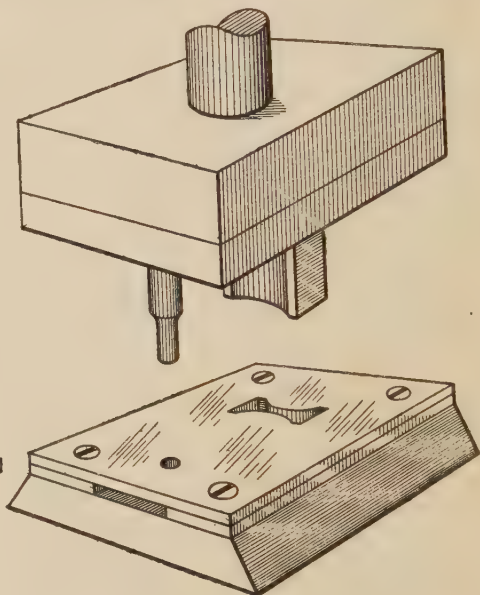


Fig. 372. Punch and Die for Making Special Copper Strips

used in piercing the hole, in forming and cutting off the ends, and producing a blank of the form shown in Fig. 373. The stock used



Fig. 373. Copper Strip after the Second Stage



Fig. 374. Copper Strip after Third Stage

is ribbon copper of the desired width of piece; this is purchased in coils and fed to the die shown in Fig. 372, by an automatic feeding device.

The pieces are next bent to form, Fig. 374, by means of the bending die and punch, Fig. 375. The third operation is done by means

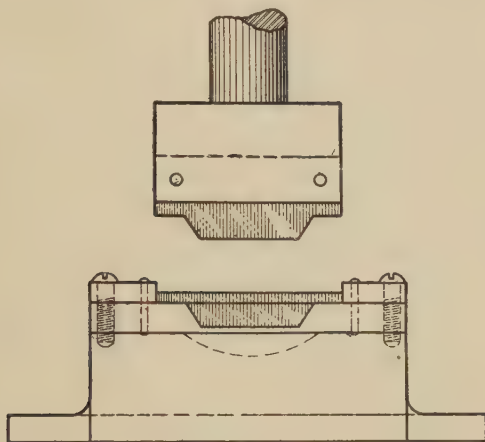


Fig. 375. Punch and Die for Bending Copper Strip at Third Stage

of the punch, Fig. 376, and the die, Fig. 377. The punch *A*, Fig. 376, folds the piece shown in Fig. 374 around the projecting portion and forms it to the shape shown in Fig. 378.

Although it might be possible to bend a piece of this description in a compound bending die at one operation, it is doubtful if the ultimate cost would be any less than that of the individual operations, as the cost of upkeep would be much greater, and the process somewhat slower. There are many jobs where it is advisable to use compound bending dies; but where there is no saving in cost of labor, or where the presses are not adapted to their use, it is best to resort

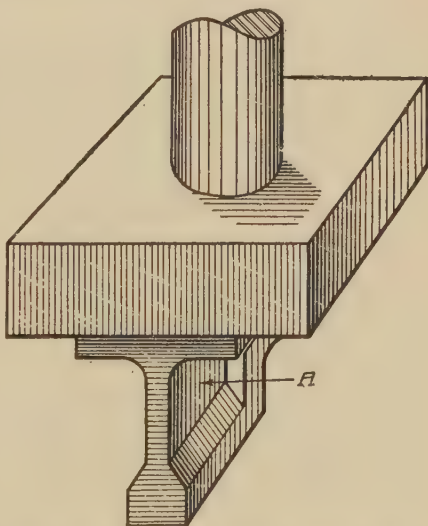


Fig. 376. Punch for Bending Copper Strip at Fourth Stage

to methods particularly suited to the individual job, even though it necessitates a greater number of operations.

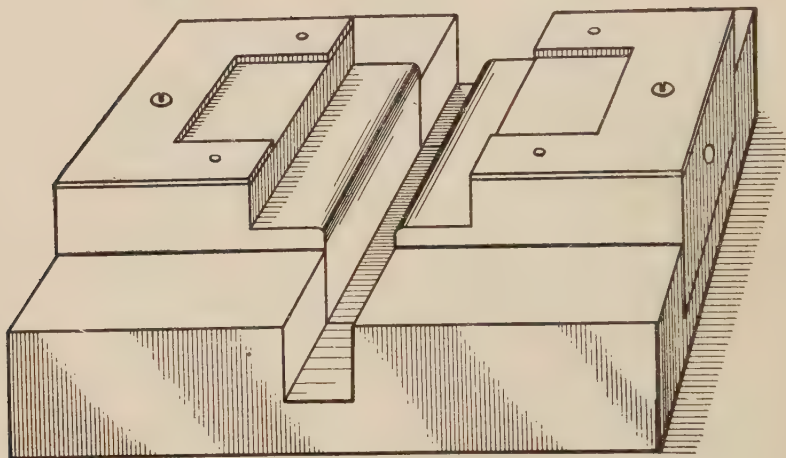


Fig. 377. Die for Bending Copper Strip at Fourth Stage

Sub-Press Dies. A sub-press is a small self-contained press which is operated by a large press. It is extensively used in watch and clock shops for punching the movements. Fig. 379 shows samples of work done on this press. Figs. 380 and 381 show different styles of sub-presses.

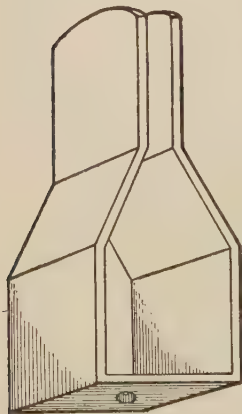


Fig. 378. Final Shape of Copper Strip

While sub-presses differ in design, the pattern illustrated in Fig. 382 is well adapted for general use. The upper portion *A* of the press, as shown in cross-section, is bored out tapering to receive the Babbitt sleeve, and the feet are bored to fit on the base. A thread is cut at the top to receive the nut used in holding the Babbitt lining tightly in place. The die goes in the base, and is made in the usual manner. The punch, which is held in the plunger *B*, is carefully

set, and the space around the plunger is filled with Babbitt metal, poured in the usual manner. In order that the plunger shall be held from turning, three or four parallel grooves are

milled as shown, before the Babbitt metal is poured, the latter, filling the grooves, acts as a guide.

The slot at the top of the plunger engages loosely in the gate of the press, so that absolute accuracy in the working of the ram of the

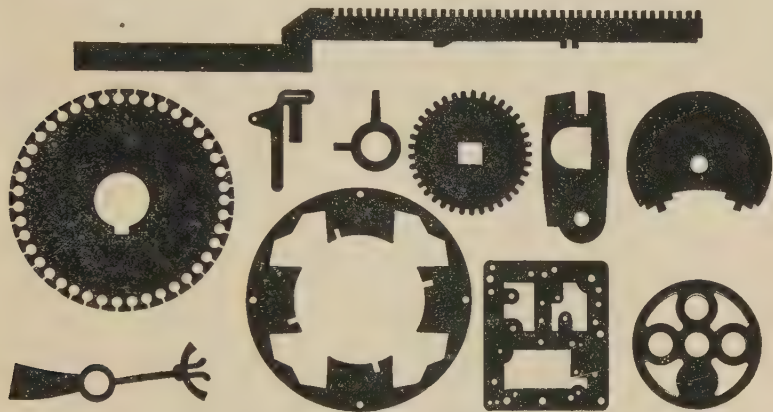


Fig. 379. Work Performed by Sub-Press

press is not essential. A good press, however, is always to be preferred. It is considered good practice to adjust the press so that the punch does not actually enter the die, but comes just far enough

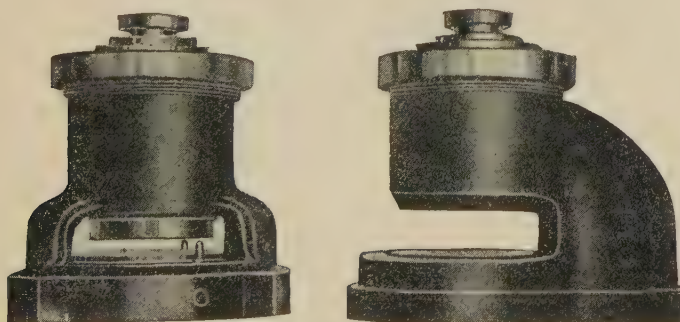


Fig. 380. Two Forms of Sub-Press

to punch the blank out of the stock without the edges of the die and punch coming in contact.

The sub-pressure is especially valuable for complicated dies, and many compound dies are used in this form. Complicated dies, which, when made in the ordinary way, would produce but a com-

paratively few pieces, will, when sub-pressed, punch from 20,000 to 50,000 pieces.

Use of High-Speed Steel for Dies. The advisability of using high-speed steel for punch-press blanking, bending, forming, and other dies, depends in a large measure on the facilities in the individual shop, for hardening tools made from this steel. If conditions are favorable, there is no doubt that many dies made from high-speed steel will produce several times the amount of work which the same die made from carbon steel will produce. This is especially

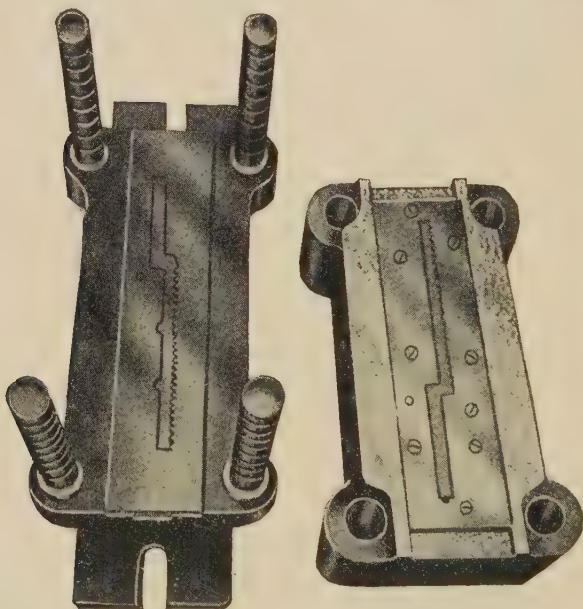


Fig. 381. View of Dies of Sub-Press

true of forming, bending, and drawing dies, where there is crushing strain and a tendency to wear from abrasion.

In making a die, as in making many other forms of tools, the principal item of expense is the labor; the difference in the cost of steel is insignificant when the life of the tool and the increased amount of work it will turn out are considered.

Dies made from high-speed steel should be pre-heated to a low red in some form of pre-heating furnace; then placed in a high-speed furnace and raised to a uniform temperature of from 1750° F. to

2100° F., after which they should be removed and immediately plunged into a bath of oil. Dies that are not to be subjected to great strain or extreme shock may be heated to the higher temperature mentioned, while those that are to be subjected to strains should receive lower heats. Different makes of steel require different temperatures on account of the varying percentages of alloys. As a result, exact temperatures cannot be definitely stated.

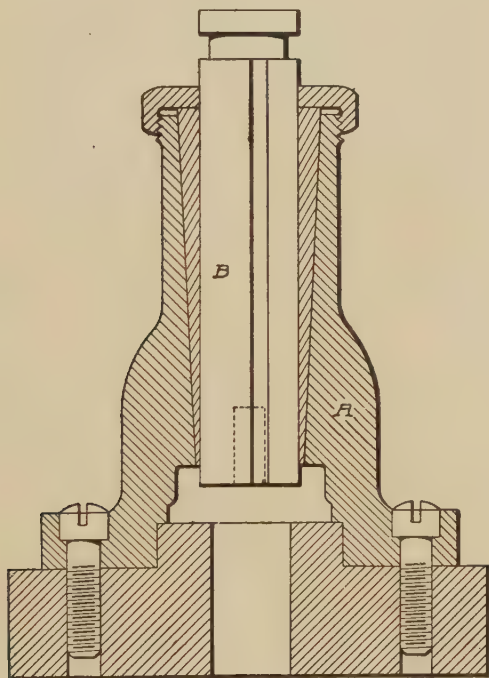


Fig. 382. A Pattern of Sub-Press

After hardening, the temper should be drawn from 460° F. to 530° F., depending on the strain the tool is to receive. If the strains are excessive, the higher temperature must be given.

Fluid Dies. These are used in the production of various kinds of hollow ware, such as vases, lamp bodies, match safes, etc. The metal may be Britannia ware, silver, or soft brass. The die is generally a casting of soft close-grained iron. It is made in several parts, as it is necessary to open it in order to get the piece out.

Fig. 383 shows a die of this description. The plunger works down through the knurled sleeve, thus causing the confined fluid,

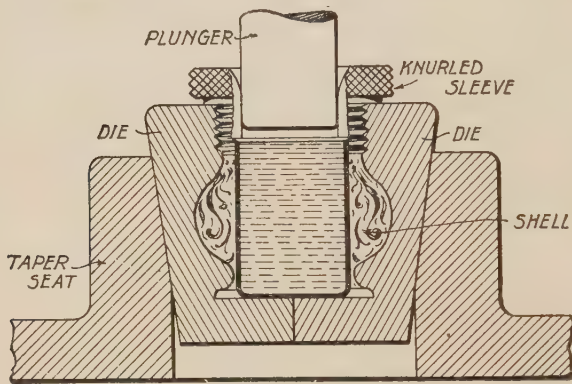


Fig. 383. Fluid Die Showing Plunger and Mold

with which the piece has been filled, to force the metal out into the impressions in the mold.

It is the custom in some factories to use soft rubber in place of the water or other fluid, the plunger pressing on it and thus swelling the metal out into the die. It is claimed that in producing clear-cut outlines and full, sharp corners, the rubber works better than a fluid.

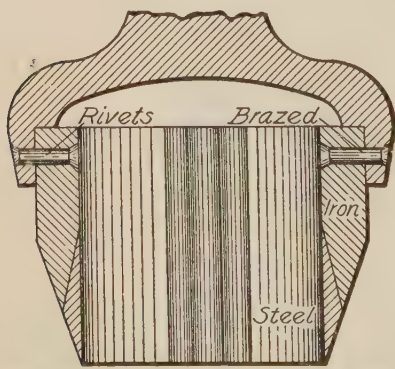


Fig. 384. Hollow Punch of Tool Steel Welded to Back of Norway Iron

Hollow Punches. When work is to be punched from paper, cloth, or leather, hollow cutters or *dinking dies* are commonly used. They give better satisfaction and are more cheaply produced than the ordinary punch and die used for blanking. Several thicknesses of material

may be cut at once, the punch may be driven through the material with a maul or mallet operated by hand, or it may be used in a press.

While the cutter may be of ordinary tool steel, it is customary to use stock made especially for the purpose, by welding a suitable

grade of tool steel to a back of Norway iron, as shown in Fig. 383, where the metal is represented in cross-section.

In some shops, the strips of iron and steel are welded as required. As a rule, however, better results are obtained if the commercial article is purchased, for the welding is done at the steel mill under conditions which insure better material and more solid joints.

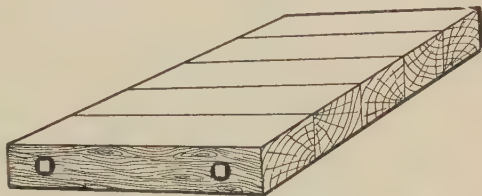


Fig. 385. Cutting Board to Be Attached on Base of Press

From a templet made for the shape of the desired opening in the cutter, the blacksmith forms the tool, and welds it. The cutting edge is beveled on the outside, as shown in Fig. 384, to an angle of about 20 degrees. After welding and shaping, the inside is filed to the desired size and shape, allowance being made for the shrinkage which takes place when the cutter is hardened.

This form of cutter can be used in a hand, foot, or power press; or it can be used by hand. If designed for a press, it is made without a handle, the cutter being brazed to a base; the brazing material is soft brass, borax being used for the flux. In some instances the cutter back is bolted to the press base, the cutting edge uppermost; in other cases, the base is attached to the movable ram of the press, and the stock to be cut is placed on a board on the base of the press. This board is made by gluing together several pieces of hard, well-seasoned maple, the pieces being arranged as shown in Fig. 385, so that the end grain of the wood forms the surfaces on which the cutter strikes. The various blocks should be securely held together by bolts in addition to the glue. After gluing and bolting, the surfaces should be worked down flat, smooth, and parallel. When not in use, the board should be dampened slightly to prevent the opening of the grain of the wood.

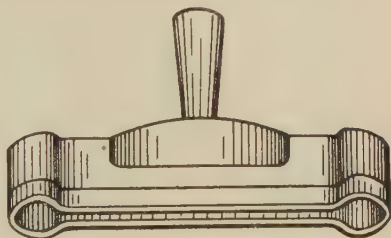


Fig. 386. Cutting Die and Handle

If the cutter is to be operated by hand, a handle such as shown in Fig. 386 should be provided. This handle is brazed to the cutter,

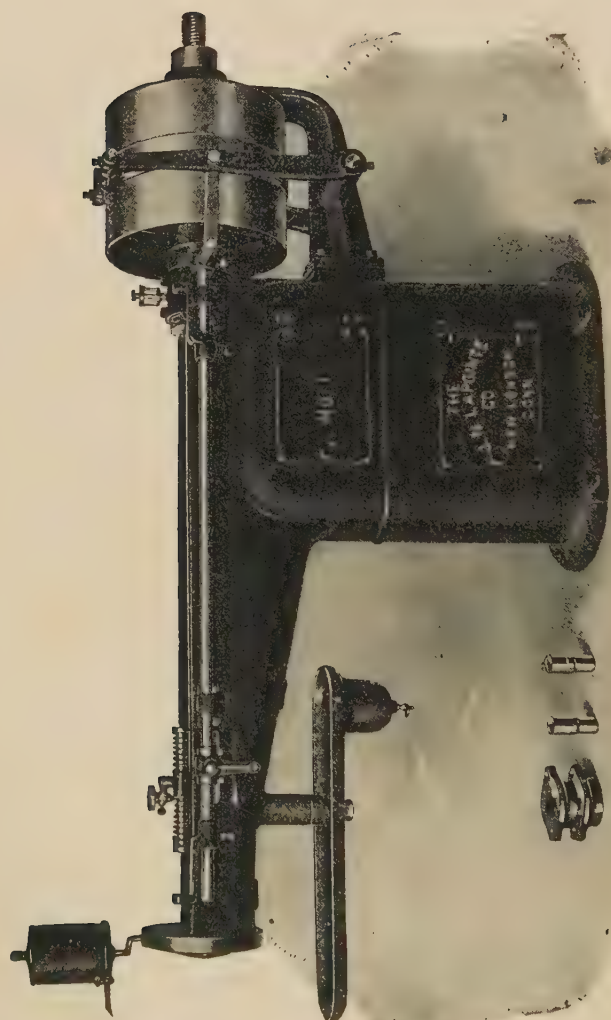


Fig. 387. Draw-Broaching Machine
Courtesy of J. N. Lapointe Company, New London, Connecticut.

usually before hardening the tool. In many shops this form of tool is called a *cutting die*.

BROACHES

The operation of broaching is many times classed under the same head as that of punching with punches and dies, as both may be done in the punch press, and when such is the case, the operations resemble each other.

Formerly all broaching was done by pushing the cutting tool—broach—through the stock. At the present time, a form of machine



Fig. 388. Samples of Work

called a draw-broaching machine is used in many shops, and the tools are drawn through the work. It is possible, with the draw broach, to make the broaches much longer than in push broaching, so that one broach of the former kind may be made to do as much work as several of the latter. In actual practice, one draw broach has accomplished as much work as twelve push broaches, and in less than one-fifth of the time, thus effecting a decided saving in time and cost of tools.

The process of draw broaching has revolutionized certain methods of manufacture, especially that of producing straight holes of irregular form running quite through pieces of work. While

broaching by means of push-through broaches has been practiced for many years, draw broaching is of comparatively recent origin. The success of the method depends in a great measure on the design and construction of the broach used in producing the hole.

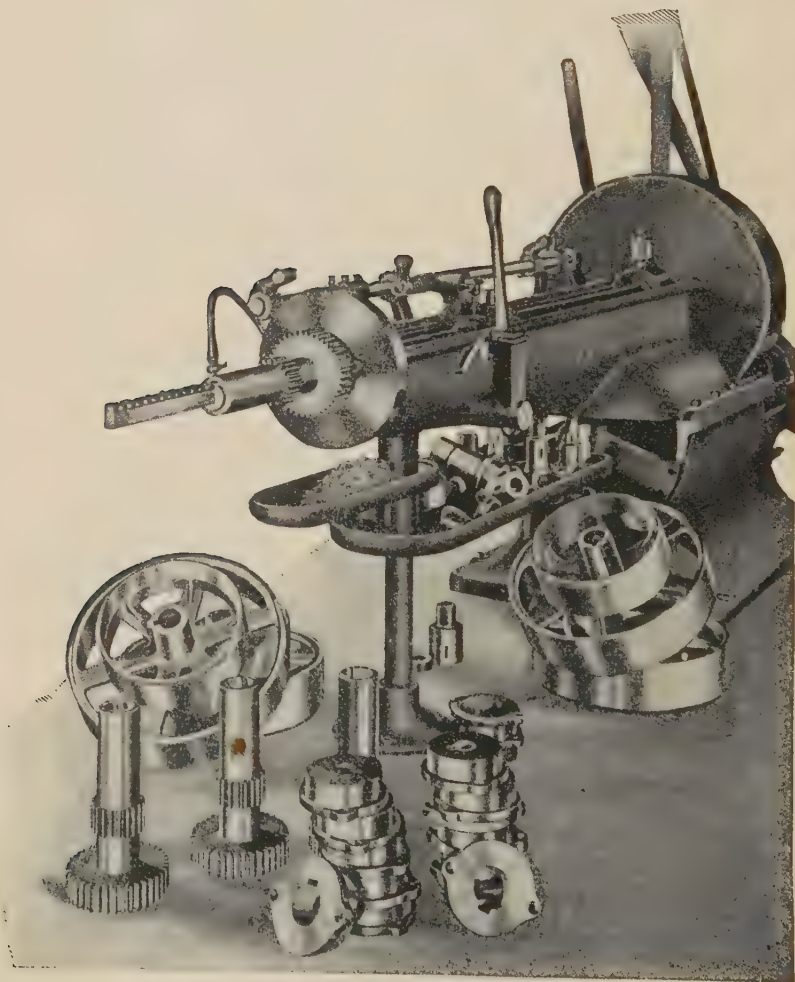


Fig. 389. Large Draw-Broaching Machine
Courtesy of J. N. Lapointe Company, New London, Connecticut

Design of Draw-Broaching Machines. Draw-broaching machines are made of various sizes and design. For light pieces having short holes, a small machine designed especially for such work

should be used, as it can be made to produce work more rapidly than a heavy machine; but if heavy work with large or long holes is to be broached, it is necessary to use a heavy, strong machine with a long pull. A small broaching machine suitable for light work that must be handled rapidly, is shown in Fig. 387, and some

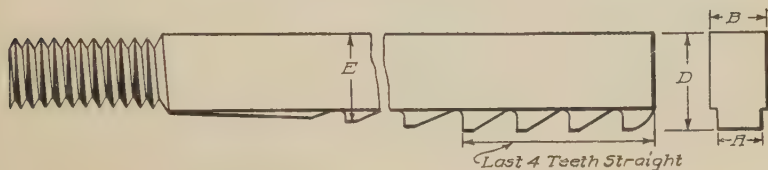


Fig. 390. Keyway Broach

samples of work done with it, are shown in Fig. 388. A much larger machine, with samples of work it is especially adapted for, is illustrated in Fig. 389.

Where a comparatively small amount of metal is to be removed by the broach, it is possible to produce a finished hole with one broach; but where considerable metal must be cut away, it is necessary to use two or more broaches, each a little larger than the one preceding it.

The time saved by draw-broaching keyways in long holes, as compared with methods formerly used, is apparent when one realizes that it takes but three minutes to produce a $\frac{5}{8}$ -inch keyway 13 inches long by the use of two broaches. On shorter work, the keyways can be cut in one operation. Fig. 390 shows a keyway broach.

The ability of a broach to do a certain amount of work is generally governed by the amount of stock to be removed, as the indi-



Fig. 391. Broach Teeth

vidual tooth must not cut away a greater amount of stock in the form of chips than can be held in the space between the teeth without interfering with the cutting. While it is customary to make broach teeth with their backs of the form shown at *d*, Fig. 391, at times it is necessary to give them the form shown at *e*, to provide a larger

chip space. The latter shape, however, does not give so strong a tooth as the former. Many times a round hole, the diameter of

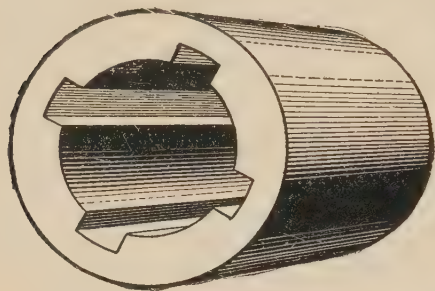


Fig. 392. Keyway Broached in One Operation

$\frac{3}{8}$ -inch keyways in a $\frac{1}{2}$ -inch hole 3 inches long, is broached in one operation by the use of a four-spline broach.

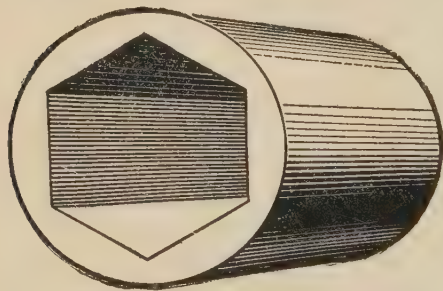


Fig. 393. Broaching Soft Steel at One Operation

is used, or longer holes broached, it may be necessary to use two, or even three broaches to produce a satisfactory hole.

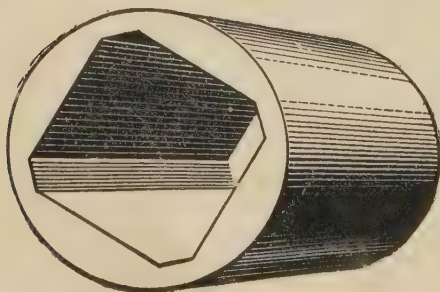


Fig. 394. Broaching Square Holes

which is a little less than the smallest diameter of the finished hole, is drilled in the piece of work, and the hole brought to the desired size and shape by drawing the broach through it.

Illustrations of Broaching. The piece of work shown in Fig. 392, which has four

The piece shown in Fig. 393, made from soft steel, is broached from a round hole in one operation by the use of one broach, the time necessary being one and one-half minutes. The broach is a hexagon $1\frac{5}{8}$ inches in diameter and the hole is 3 inches long. If harder stock

Square holes are often broached in gears and similar pieces at a single operation. As a rule these holes are made with round instead of square corners, Fig. 394. This form of hole is designed to give greater strength to the piece, and is used especially where the work is to be subjected to

great strain, and where square corners would be a source of weakness. If necessary, the broach may be made to produce square corners.

While it is possible to broach a large variety of forms and sizes of holes at a single operation, yet for certain jobs—as, for instance, the piece of work shown in Fig. 395—several operations are required. A portion of the piece, that is one notch, is cut at a time, the work being held in an index fixture so designed that the piece can be turned one-sixth of a revolution after each broaching operation, and the process repeated until all six notches have been produced. The forging, which is 6 inches in diameter and $1\frac{1}{4}$ inches thick, had a hole 4 inches in diameter bored in it before the piece was taken to the broaching machine to be notched.

Fig. 396 shows how the teeth of an internal gear are produced by broaching with an index fixture. In doing this class of work, as in cutting keyways in round holes, it is customary to guide the broach with bushings. The bushings fit the hole in the work and receive the broach as shown in Fig. 389, or are attached to the machine and so guide the broach in the proper location.

We have shown but a few of the many varieties of work that are satisfactorily produced at a relatively small cost by draw broaching.

Under certain conditions round holes are produced by round broaches instead of being reamed. This is satisfactory for some classes of work, and the cost of finishing to size is much less than by reaming.

Fig. 397 shows a broach which does no cutting. It is employed to size holes in Babbitt metal and other alloys used for bearings, where it is advisable to compress the metal to give good wearing qualities. The broach is drawn through the same as any broach, and leaves a smooth hole, true to size.

In a great many cases, broaches of various forms are made to start in a round drilled or cored hole; at other times the starting hole may be rectangular, Fig. 398, or of some other form where



Fig. 395. Broaching that Takes Several Operations

the core may be drilled and broken out as shown at *a*, Fig. 399. or the rough holes may be produced in the die if the piece is drop-forged as shown at *b*. The finished broached hole in the connecting rod, as shown in Fig. 398, is $4\frac{1}{2}$ inches long by $2\frac{1}{4}$ inches wide.

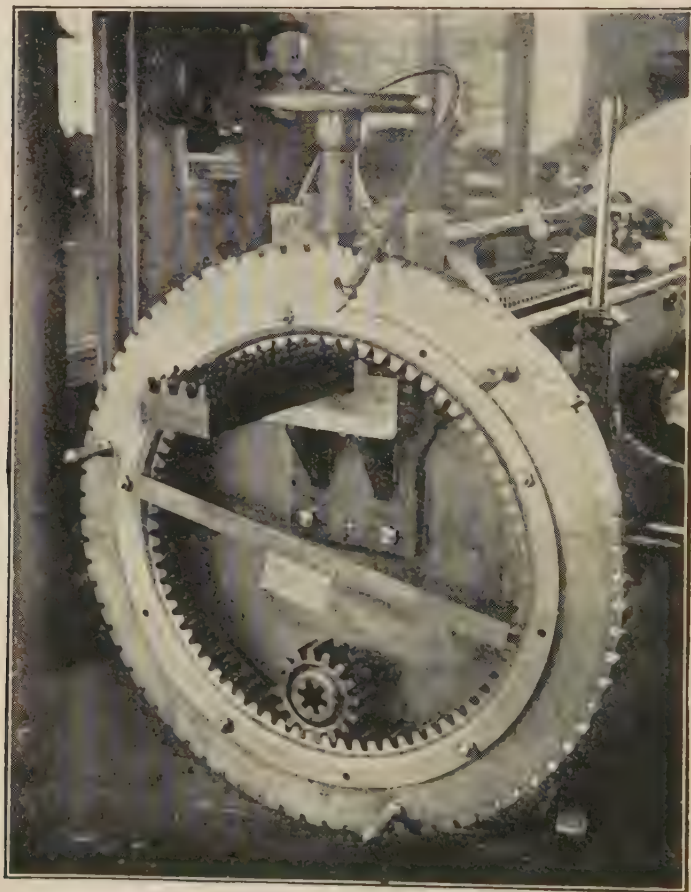


Fig. 396. Broaching Teeth of Internal Gear
Courtesy of J. N. Lapointe Company, New London, Connecticut

The length of the hole that can be broached with one broach is usually twice its diameter. For instance, if the broach is 1 inch square, it can be used to broach a hole 2 inches long. When the work is of greater length, two or more broaches are required, depending, however, upon the nature of the metal being broached, and

also upon the form of the broach, as the larger the round corner, the easier the pull on the broach. If absolutely sharp corners are



[Fig. 397. Broach That Does Not Cut

made, the shorter will be the length of hole that can be broached, and, in case of long holes, the greater the number of broaches that

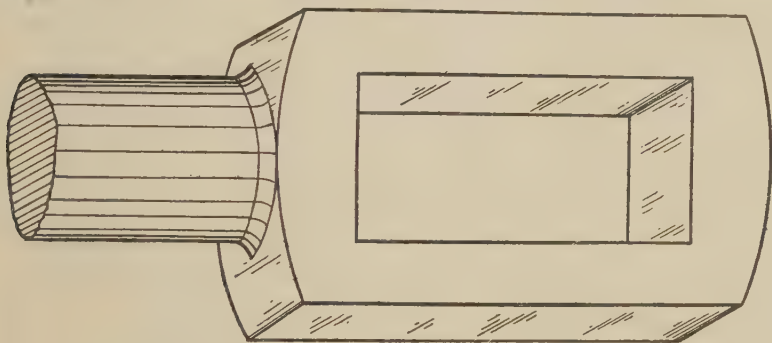


Fig. 398. Connecting Rod with Rectangular Starting Hole

must be used. The length of the hole that can be broached must be determined by the capacity of the machine.

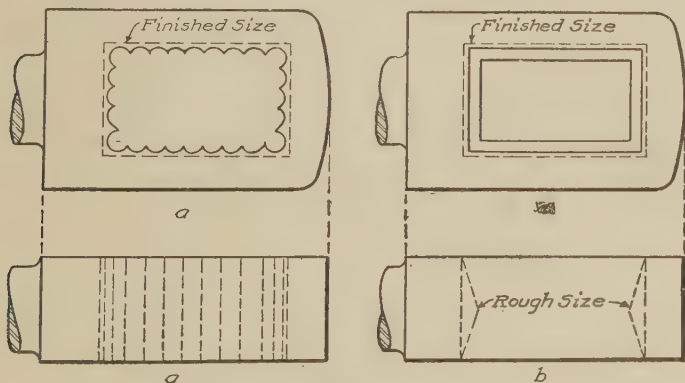


Fig. 399. Method of Broaching Rectangular Hole

Stock for Broaches. *Alloy Steel.* Broaches should, as a rule, be made from a good grade of crucible tool steel. Several of the alloy

steels work exceptionally well for broaches that are to be subjected to heavy pulls; this is especially true of vanadium tool steel, the vanadium renders the steel stronger and tougher, and its presence in the steel also increases the range of heat that can be employed when hardening, without augmenting the brittleness. The manufacturers of these steels recommend a hardening temperature of from 1350° F. to 1425° F., grading the heat according to the diameter of the broach. The temper should be drawn to a full straw color—460° F.

Oil-Hardening Steels. There are several oil-hardening steels that work well for many kinds of broaches. Their nature varies so much that it would not be wise to give specific instructions for their use. In case they are employed, it is best to obtain instructions for their treatment from the individual makers.

High-Speed Steel. High-speed steel is used for some classes of broaches, but it is not advised unless the designer is familiar with the limitations of this steel for this particular class of work. In some cases where conditions are favorable, high-speed steel broaches used on malleable cast iron give exceptionally good results.

Carbon-Tool Steel. Regular carbon-tool steel when used for draw broaches should ordinarily contain from 1.0 to 1.1 per cent carbon, although excellent results follow the use of steel containing 1.25 per cent carbon, if the pull is not too great; in the latter case, the lower carbon content is to be preferred.

Open-Hearth Steel. For broaches that are not to be subjected to great pulling strain, a good grade of basic open-hearth steel containing thirty points carbon works well, especially where the broaching is done directly from a cored or forged hole and where the broach is to be subjected to considerable vibration. Broaches made from this material must be pack hardened.

Making Draw Broaches. *Cutting and Turning to Size.* No general method can be given for making all forms of draw broaches, as the desirable method depends on the form of the finished tool. If the broach is to be used for producing square, hexagonal, or other holes, with round corners, from a round drilled hole, select steel adapted to the individual job. Cut the steel to length, then center and square the ends; after which it should be rough-turned, and the shank turned to finish size, which is generally the size of the

drilled hole. However, if the end of the shank is to fit some holding device that goes with the machine, then that portion must be turned to that size as shown in Fig. 400. This, of course, must not be larger than the drilled hole.

The balance of the piece should now be turned to the largest diameter of the broach plus a small amount for finish, and tapered

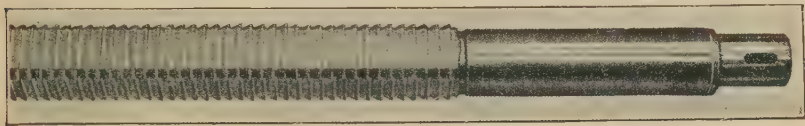


Fig. 400. Typical Pull Broach Showing Method of Holding End
Courtesy of J. N. Lapointe Company, New London, Connecticut

from the teeth nearest the fastened end to within four teeth of the opposite end; this end should be straight in order that the last four teeth may all be of a size to allow for wear, Fig. 390. Having the four teeth of finish size insures correct sizing of holes, even after the cutting teeth have been sharpened several times.

Annealing. Many tool-makers who make a specialty of broaching tools always anneal the broach after the teeth have been blocked out. After annealing, the teeth are cut to depth and the broach finished and hardened.

Cutting Teeth. If the broach is to produce a square hole with round corners, Fig. 394, the teeth may be first produced on the lathe on the round piece, Fig. 391, with a tool that will produce a cut of the desired form and depth. The spacing can be obtained by means of the lead screw, or, with a spacing block and clamp with a set screw, Fig. 401. The clamp should be attached to the bed of the lathe and the screw set against the space block as shown. The block, the thickness of which corresponds with the desired pitch of the teeth, is removed, and the carriage moved along against the screw. In this way, the

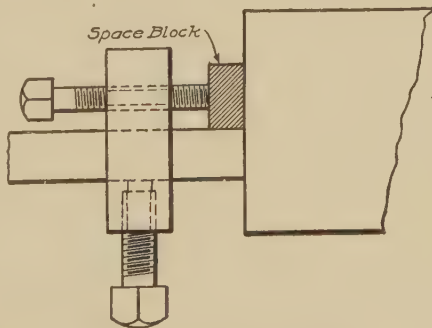


Fig. 401. Spacing Block and Clamp

teeth are spaced exactly alike for the entire length of the cutting portion of the broach.

Before the broach is removed from the lathe, the tops of the teeth should be backed off for clearance, as shown at *c*, Fig. 391, by means of a flat-nosed tool. After all the teeth have been backed off, the broach should be placed between the index centers of the milling machine, and one center raised or the other lowered to the taper of the broach and the flats milled. The large end—that is, the last four teeth—should be milled to the desired dimensions parallel to the axis.

The teeth on the flat portions may now be produced by milling or planing, to correspond in shape and depth to those on the round corners.

Filing Teeth. It is necessary to have the face and the back of the tooth smooth in order that chips will be cleared readily. This can be secured by filing, and should be done before the top surfaces that make the clearance angle are filed. Previous to filing the surfaces of the clearance angle, apply copperas in order that the workman may see where he is filing. File to the cutting edge, but do not remove any stock from the edge, because if one tooth is made short, the next tooth must do double duty. As previously stated, the four teeth at the large end of the broach should be of equal diameter if the tool is to hold its size.

Pitch of Teeth. The *pitch* of broach teeth cannot be stated arbitrarily, for the distance from one tooth to the next depends in a great measure on the amount of stock to be removed, the length of the broach, and the thickness of the piece to be broached. The following formula, however, is used by some manufacturers of broaches for use under average conditions:

$$P = \sqrt{L} \times 0.35$$

where P = pitch, or distance apart of teeth; and L = length of hole to be broached. For example, if a broach is to be made for broaching a hole 4 inches long, the distance between the teeth would equal 2×0.35 , or .7 inch, approximately. In the case of a broach of large diameter, it is possible to cut the teeth deep and a little closer together than if the broach were of smaller diameter, as in the latter case the teeth must be shallower to give strength to the broach. It is always

necessary to design the broach with the teeth so spaced and of such depth that the space between them will hold the chips removed, for otherwise the chips would wedge themselves between the broach and the walls of the hole, thus tearing the surface of the walls, and in all probability breaking the broach.

Size of Teeth. The variation of size of adjoining teeth cannot be stated arbitrarily. Under average conditions, an increase in size of from .001 to .003 inch works well on steel, and from .002 to .004 inch on cast iron or brass. Yet working conditions and the character of the material make it possible and advisable to change these amounts of increase in size at times.

If the broach has long cutting teeth, it is advisable to nick them to break the chip, as the long chip, especially if it is steel, would be likely to cause trouble. When nicking the teeth, make sure that no two adjoining teeth have their nicks in line.

Angle of Teeth. The face f , Fig. 391, of the teeth of broaches is many times made at right angles to the axis of the broach. A tooth cut as shown at a , however, will require less force to pull it through the work if made at an angle, yet under ordinary conditions the shape shown at b is considered the better one.

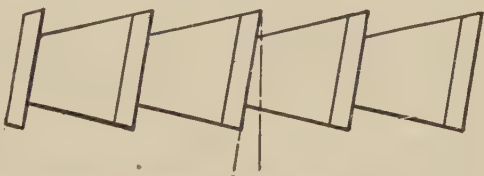


Fig. 402. Diagram Showing Angle of Broach Teeth

The clearance angle, c , is generally about 2 degrees, although at times but 1 degree is given.

The teeth of broaches are sometimes made at an angle, as shown in Fig. 402. In the case of square and rectangular broaches, teeth on opposite sides are made at opposite angles in order to balance the cut.

Hardening. When hardening broaches, it is necessary to heat them uniformly their entire length, a process best carried on in an oven furnace or in a piece of pipe in an ordinary furnace. In order to get a uniform temperature, the piece should be turned frequently. When it has become uniformly heated to the proper temperature, plunge it vertically in a bath of warm, not hot, water in which a quantity of salt has been dissolved, and work up and down until

cooled to the temperature of the water, when the broach may be removed and tested for straightness. If it has sprung in the operation of hardening, it may be straightened in the following manner: Place the broach in a screw press or a drill-press table on two blocks of *hard* wood, then, with a spirit lamp or bunsen burner,

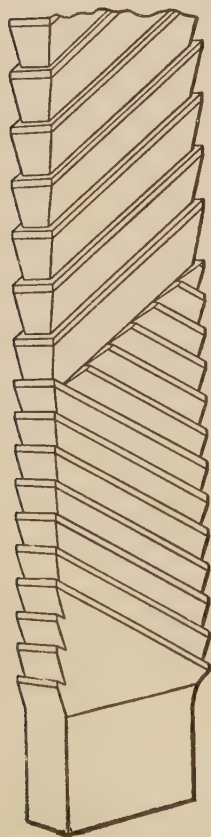


Fig. 403. Typical Push Broach

heat it until lard oil on the surface smokes; now, with a third block of wood between the work and spindle of machine, apply pressure by means of the spindle until the tool is straightened. It will be necessary to do all the straightening before the temperature drops much, or the broach will break. After the straightening, the temper may be drawn. Some hardeners, who are quite skilful in this particular line of work, straighten and draw the temper at one operation. Broaches made from oil-hardening steels are heated as described above and hardened in oil. Broaches made from low-carbon open-hearth steel are packed in charred leather in a piece of gas pipe, the ends of which are sealed, and the whole subjected to a red heat for several hours, the time depending on the size of the piece. When the carbon has penetrated to the desired depth, the broach is removed from the pipe and plunged vertically into a bath of hardening oil; or, if a harder effect is desired, into a bath of lukewarm water.

After hardening, the broach should be tested for straightness; if it has sprung, it should be heated and straightened, as previously described, and the temper drawn to a light straw color.

Long Broach vs. Short Broach. Generally speaking, the length of a broach depends on the amount of stock to be cut out of the hole, and the capacity of the machine. Some broach-makers, however, believe it is economy to use several short broaches instead of one long broach, even where the capacity of the machine makes it possible to use a long one, maintaining that long broaches are more costly to make, and more likely to break when

in use. The advisability of either depends on so many factors that are peculiar to the individual shop, that it is not possible to make any general statement that will fit all cases.

Push Broaches. Broaches of the form shown in Fig. 403, are called push broaches, and are used in special presses having an adjustable stroke of from $1\frac{1}{2}$ to 12 inches. It is generally necessary to use several broaches in finishing a hole, especially if they are short. At times it is desirable to use a long broach in a press having a comparatively short stroke. This may be accomplished by using blocks. First drive the broach into the work as far as possible with the stroke of the press; then, when the ram is at the top of the stroke, insert a block the thickness of which is equal to the stroke of

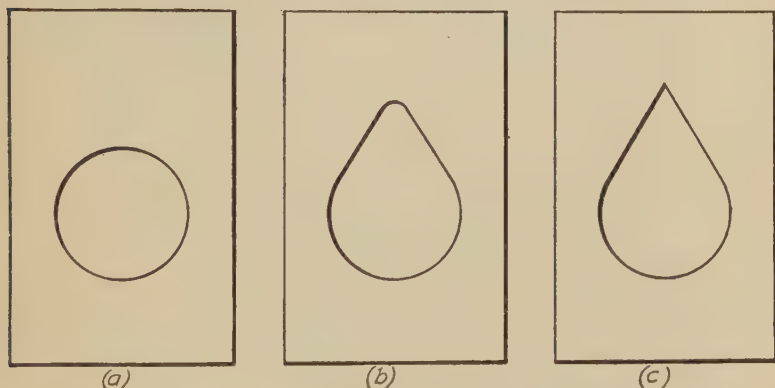


Fig. 404. Progressive Punchings of Keyseating Machine

the press between the ram and the top of the broach. At each successive stroke of the press, use a thicker block.

When broaches are used in a press, it is always advisable to use a driver having a V-shaped opening in face.

Keyseating Machine. For many jobs a keyseating machine is an absolutely essential part of the equipment. Where work is done in small lots, it is frequently advisable to use this machine instead of a broaching machine, as the cost of cutting tools is but a fraction of the cost of a broach.

At times this machine is used to remove a portion of the stock before broaching, as is the case with the piece shown in Fig. 404. A hole is drilled in the piece, as shown at *a*; the piece is then placed in the keyseating machine and the hole cut to the form shown

at *b*, after which it may be brought to finish size and shape *c* by broaching.

Irregularly shaped holes that are larger at one end than at the other, as shown in the circular piece, Fig. 405, are easily

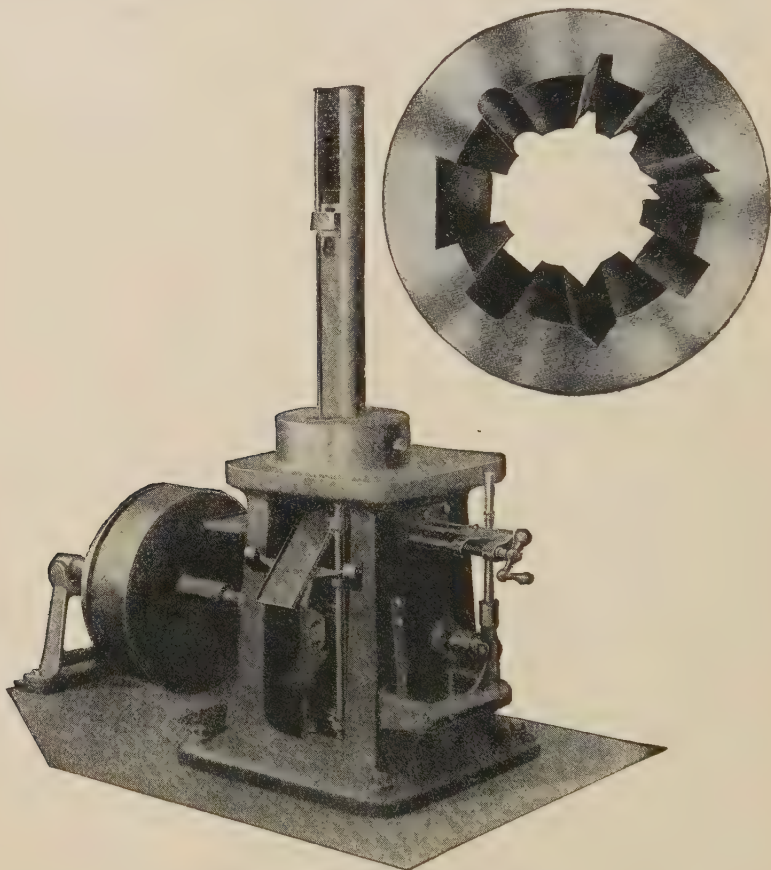


Fig. 405. Keyseating Machine and Sample Keyseats in Taper Hole
Courtesy of Mitts and Merrill, Saginaw, Michigan

machined in a keyseating machine by the use of properly shaped cutting tools and rightly designed holding fixtures.

DROP-FORGING DIES

It is extremely difficult, as well as very costly, to produce many forgings by hand, if it is necessary that they be of uniform size and form. As the tendency in all up-to-date shops is to produce

duplicate work, and many parts are turned out by forging, dies are made which have the shape of the piece to be forged cut into the faces. A forging of the desired size and shape is produced by forcing the heated metal into the impressions.

Drop=Forging Process. In forging, the dies may be held in forging machines of various kinds, such as the *forging press*, the *bulldozer*, the *drop press* (where the ram is raised by means of rolls acting on a board attached to the ram or head), or the *steam drop*, Fig. 406. Although the *board drop*, Fig. 407, is the form most commonly used, it is giving way in many places to the steam drop on account of the more positive and speedy action. It is frequently necessary to use several sets of dies, or several sets of impressions in the same dies; *first*, a breaking-down impression; *second*, a roughing impression, and *third*, a finish impression.

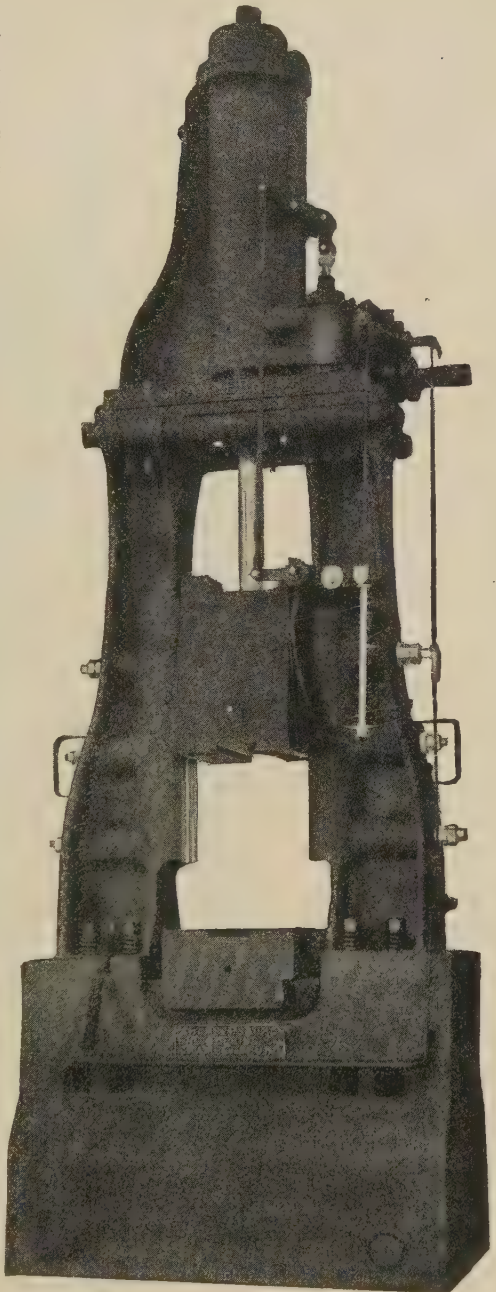


Fig. 406. Chambersburg Steam Drop Hammer

Considerable experience, coupled with good judgment, is required to lay off properly a breaking-down impression in a



Fig. 407. Board Drop Hammer
Courtesy of E. W. Bliss Company, Brooklyn, New York

forging die, in order that the material may be rightly distributed so as to fill the other impressions without excessive waste of stock.

A die-maker with limited experience in laying out dies should give special attention to the laying out of breaking-down impressions in order that he may be able to do this kind of work in a satisfactory manner.

After forging, a quantity of surplus stock will show around the desired blank; this is called the *flash*. The flash is removed by forcing the forging through a *trimming die*. The impression in the trimming die is the exact shape of the forging, and the forging passing through has the flash cut away. Large forgings are trimmed while red hot, and the operation is known as *hot trimming*, while small forgings are generally trimmed cold, and the process is called *cold trimming*.

Making Drop-Forging Dies. *Stock.* Drop-forging dies are made from crucible steel which is furnished in the form of die blocks in any desired size; or, as is the case in many shops, they are made from open-hearth steel, in which case they are procured from the mill in pieces of the proper size, or the stock is purchased in bars and cut up and forged to size as wanted. The latter method proves satisfactory where the equipment of the shop allows the heating and handling of pieces of metal weighing several tons. As it is then possible to cut off, forge, and anneal pieces of almost any size, there is very little waste.

Small dies are generally hardened, while large dies seldom are. Large dies that are not to be hardened are often made from steel containing a proportion of nickel, or other alloy that insures desired ability to stand up when in use.

Cutting. Most die blocks are planed to size after annealing, although in some shops they are milled to size. The tang is produced by either planing or milling, according to the equipment of the shop. The impressions are carefully laid out on the faces of the dies by means of templets, and the metal cut away with milling machine cutters, the work being done in a die-sinking machine. The cutters are made of a taper that produces the proper draft in the die. It is necessary to give the impression sufficient draft so that the forging will not stick in the die. The draft which should be used varies from 3 to 5 degrees.

As it is not possible to get into corners with milling cutters, it is frequently necessary to remove some of the stock with a cold

chisel, scraper, and files. Die-sinkers use a special type of file in working the walls of the impressions; these are of various forms and are bent to allow of use in the impressions. They are called *rifflers*. In Fig. 408 are shown various special forms of files and rasps.

Casting Lead. After the impressions in the die are finished to size and shape, the dies are clamped face to face, and lead is poured

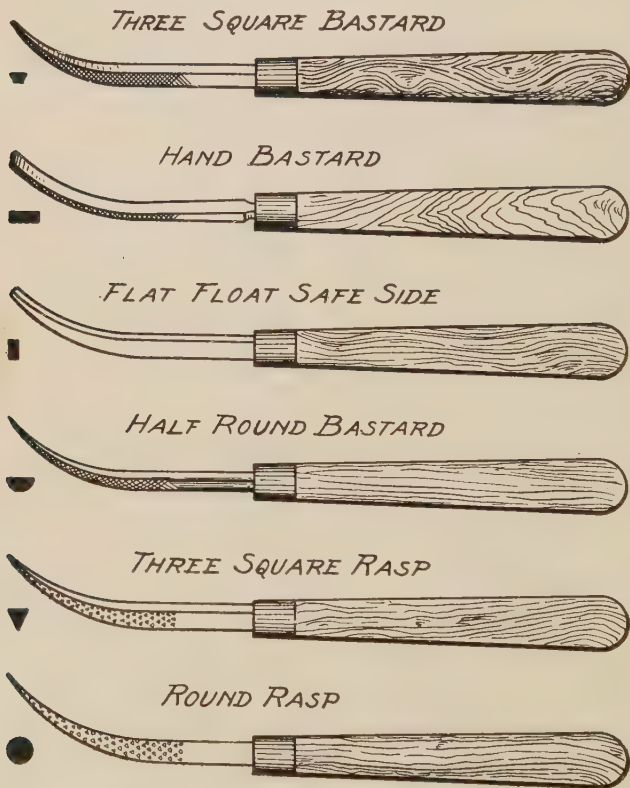


Fig. 408. Special Forms of Files and Rasps

into the impressions. The resulting piece, known as the lead, is measured, and, if found correct, is marked and laid away for reference. In some shops the die faces are blocked apart when the lead is cast. After casting, the blocking is removed, the dies are placed in a hydraulic press, and the lead is forced out into all parts of the die; if a flash is thrown out between the dies, this may be cut away and the lead pressed again. As a rule, the pressing of a lead is not

the practice, as it is necessary to allow for shrinkage and this involves the use of tables of coefficients of expansion of metals.

If the lead, when measured, is found not to be of the desired size, sufficient stock may be removed to give desired results, and another lead cast.

For many dies, it will be found necessary to cut away the faces of the dies around the impressions, Fig. 409, to provide a place for the flash, in order that it may not lie between the dies, and so produce forgings of varying thickness.

Stamping Identification Marks. When the die blocks are finished, and before they are hardened, the name of the piece to be forged in the die, as well as the shelf number of the die, should be stamped on one or both ends of each. While this might not seem necessary in the shop having only ten or twelve sets of dies, it *is* necessary in the shop having hundreds, some of which are seldom used. If the dies are kept in a certain place on certain shelves, and a record is kept of the dies and the shelves, it is an easy matter to find any die, at any time.

Hardening. When hardening drop-forging dies, it is necessary to employ some form of heating furnace that will insure heats of the proper temperature—in other words, a furnace that can be easily and quickly regulated. The die should be heated rapidly, yet not faster than is consistent with uniform heating, or the corners and light sections will be overheated and weakened.

If large pieces of steel are placed in a furnace and allowed to remain exposed to the direct heat and to any air that may be in the furnace, their surfaces are likely to become decarbonized. As the faces and walls of the impressions of forging dies must be hardened, it is desirable to protect them. This is sometimes done by placing a quantity of granulated charcoal in the furnace on the hearth, and laying the face of the die on this. A more satisfactory method

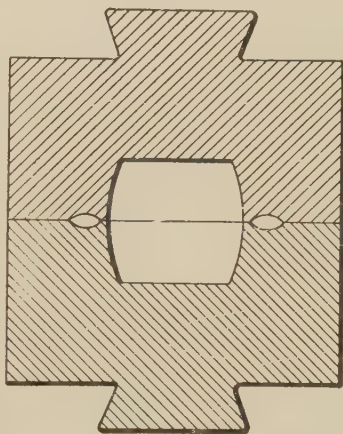


Fig. 409. Die with Faces Cut Away to Provide for Flashes

consists in placing one or two inches of granulated charred leather in the bottom of a shallow hardening box, laying the face of the die on the leather, then filling the box with leather, as shown in Fig. 410.

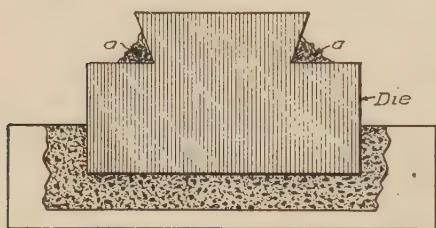


Fig. 410. Hardening Box with Die in Charred Leather

on the character of the pieces to be hardened. One form that is satisfactory for most work of this kind, has the die resting upon the supporting wires, Fig. 411. The overflow pipe should be telescoped, thus enabling the operator to regulate the depth of water in the tank. To prevent the tang from becoming distorted, it is advisable to quench this portion first; this is accomplished by placing the die, tang down, on the wires, and allowing the stream of water from

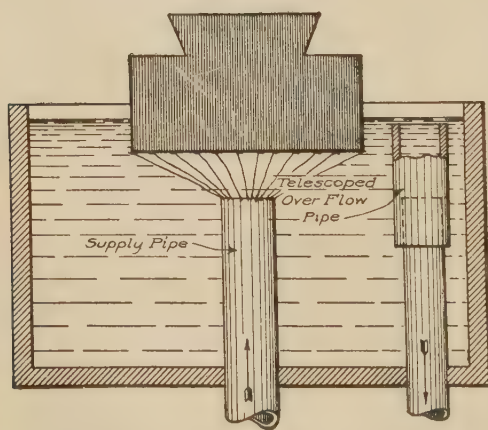


Fig. 411. Form of Hardening Bath with Die on Supporting Wires

The die may then remain in the furnace until it is uniformly heated throughout. To prevent unequal heating in the corners at base of the tang, the corners are filled with fire clay, as shown at *a*.

The form of bath depends somewhat, of course,

on the supply pipe to play against the tang. The die should be left in this position until the tang is cooled below a red, when the die should be turned to bring the face down, and the supply stream allowed to play against this portion until it is hardened.

To prevent the tang from softening before the face becomes hard, turn water, by means of a

dipper, on to the tang until the red has disappeared from the face; then cease pouring on to the tang and allow the heat to work from the center of the block up through the tang, which will in all probability be reheated to a low red.

After the block has cooled, it should be placed over a fire and heated to remove hardening strains. While heating, the surface may be brightened and the heat continued until the temper is drawn the desired amount.

At times it is necessary to harden a die having slender projections or some weak portion which is likely to crack during the process. Cracking results from the unequal contraction of the various parts, and can be avoided by rubbing soap on the projection, especially where it joins the die; or, by means of an oil can, a little lard or sperm oil may be applied to these parts. This should be done after the die is red hot, and just before it is placed in the bath. If the

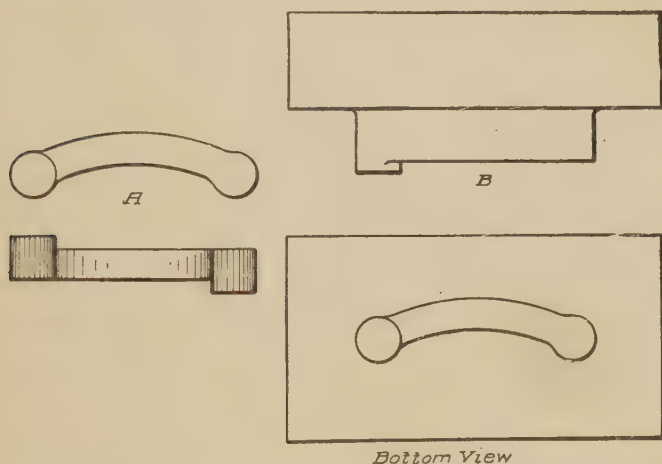


Fig. 412. Hobbing Drop-Forging Dies. *A*—Piece to be forged; *B*—Hob

tang is quenched first, the oil may be applied just before the die is turned to harden the face.

Hobbing Drop-Forging Dies. It is the custom in some shops to produce the impression in the face of forging dies with a male die, or hob, as it is called. A hob is made of the same general shape as one-half of the piece to be forged, but exactly opposite the shape of the impression desired in one die. Another hob is made the shape of which is the opposite of the impression desired in the other blank.

Making Impression. Fig. 412 shows a piece to be forged, *A*, and a hob, *B*. The hob has a shank that fits a holder in the ram

of the drop hammer. The hobs are hardened before using, and after hardening, one of them is placed in the holder in the ram; the die block is heated to a good forging heat and securely fastened to the anvil of the drop, and the hob is driven into the face of the die. This operation is repeated until the impression is considerably deeper than that desired when finished. This is necessary as the top surface of the die must be cut away to remove the rounded portion at the top of the impression, occasioned by the stock drawing away in the hobbing.

Cleaning and Smoothing Impression. After driving the hob to the required depth, the block is reheated and annealed. When the block has cooled, the scale on the surface of the walls of the impression is removed by filling the impression with a solution of sulphuric acid and water—one part acid, and two parts water. After the scale has been removed, the acid should be turned out and the surface well washed, first with hot water, then with a strong solution of potash, and then, once more, with water. The surface, when dry, should be oiled to prevent rusting.

Cold-Dropping Impression. The walls of the impression may now be finished smooth with scrapers and files. After the surfaces are finished, it is the custom in some shops to cold-drop the impression, that is, to place the die in the drop hammer again and drop the hob into the impression while the steel is cold. This custom, however, is not generally observed. After finishing, the dies are hardened in the usual manner.

Preventing Oxidation. A saving in labor may be effected, if, when the die is heated for annealing, the impression is filled with fire clay mixed with water to the consistency of dough. The fire clay prevents the air coming in contact with the steel, and does away, to a great extent, with oxidation.

Cold-Striking Dies. Many times pieces are forged which cannot be brought near enough to desired size by hammering when hot; or which must be much stiffer than hot-forging would leave them. In such cases cold-dropping or cold-striking, as it is sometimes called, must be resorted to.

After the pieces are hot-forged to a size slightly larger than finish, and the flash is trimmed away, they are pickled to remove the scale incident to the high forging heats. After pickling, and

when they are cold, they are again taken to the drop hammer and given one or more blows, in dies known as cold-striking dies.

The impression in a cold-striking die is made of the desired size of the finish piece, as no allowance need be made for contraction of the metal as is necessary when hot-forging. Since there is much greater strain on a cold-striking die than on one used for hot-forging, it is necessary to harden the former much deeper than the latter to prevent sinking when the die is used. For this reason, the dies should be made from steel having a comparatively high-carbon content.

While a large percentage of dies used for hot-forging are made from open-hearth steel, those used for cold-dropping are made from crucible tool steel. In many forging plants, this class of die is made from alloy steel prepared specially for this purpose; in such cases the heat treatment may be somewhat different from that given similar dies made from crucible tool steel. As the treatment varies for steels of different makes, it is necessary to follow the instructions furnished with the steel.

GAGES

Gages are used in machine shops to make one part of a machine, apparatus, or tool correspond with some other part, so that when the whole is assembled, every part will go in its place with little or no fitting.

In shops where work is made on the interchangeable plan—that is, where a piece of work made today will exactly duplicate a similar piece made at some time in the past—a very thorough system of inspection is necessary. In order that the inspection may accomplish the desired result, gages are made that show any variation of the pieces from a given standard. There are several forms of gages designed for various classes of work, but only those in common use in the general machine shop will be considered here.

General Directions for Making Gages. Gages are generally made of tool steel; but hardened steel has a tendency to change its size or shape for a considerable time after the hardening has occurred. This change is ascribed by acknowledged authorities to a rearrangement of the minute particles or molecules of the steel, whose original arrangement had been changed by the process of

hardening. While this change of size or shape is small, so small, indeed, that it need not be considered, except in the case of gages where great accuracy is required, yet it has led some manufacturers to use machine steel.

If tool steel is used, the tendency to change shape may be overcome to some extent by grinding the gage to within a few thousandths of an inch of finish size, and allowing it to "season" as it is termed among mechanics; that is, it is laid aside for a few months or a year, before being finished to size. This method is, of course, open to serious objection if the gage is needed for immediate use.

To save time, it is customary in many shops to draw the temper to a straw color, allowing the gage to cool slowly and repeating the operation several times. It is necessary to brighten the steel each time before drawing the temper in order that the colors may be readily seen; as this has a softening effect, the gage will not last so long as if left hard.

Accuracy Required. When making gages the workman should observe the points emphasized with regard to "approximate and precise measurements" in the first pages of this book. While gage-making is generally considered very accurate work, unnecessary accuracy should not be used. If a gage is intended for work where a variation of .005 inch is permissible, it is folly and a waste of time to attempt to make it within a limit of variation of .0001 inch. On the other hand, if the gage is to be used as a test gage on work requiring great exactness, it is necessary to use every possible effort to attain that end.

If a gage is to be made of tool steel, it is necessary first to remove all the outside portion (skin) of the stock, and block the gage out somewhere near to shape; it should then be thoroughly annealed. If the gage is flat and should spring while annealing, it should *not* be straightened cold, as it would be almost sure to spring when hardened.

It is necessary to stamp the name of the part to be gaged and the sizes of the different parts of the gage. The workman should bear in mind that the effect of driving stamps, letters, or figures into a piece of steel will be to stretch it; consequently, it is advisable to stamp the gage before finishing any of the gaging portions to size, even if there is an allowance for grinding.

Plug Gages. Plug gages are those used to measure the size of a hole.

To make the plug gage shown in Fig. 413, stock should be selected enough larger than finish size to allow for turning off the decarbonized surface. After roughing out, the handle *B* should be turned to size and knurled, the portion *C* should be turned to size and finished, and the spot in the center of the handle should be milled. The size of the gage and any distinguishing mark or name of the article to be gaged may be stamped at *B*, as shown, or, as is the custom in many shops, it may be done at *C*. After stamping, the gage end *A* may be turned to a size .010 or .015 inch larger than finish, to allow for grinding. Plug gages should be heated very carefully for hardening, as the lower the heat, the more compact will be the grain; and a piece of steel whose grain is fine and compact will wear better than one whose grain is coarse. If the gage is one requiring great accuracy, it may be left .0025 or .003 inch above size and allowed to season, provided this precaution is deemed necessary; if not, the gage may be ground to a size .001 inch larger than finish, after which it must be lapped to finish size.

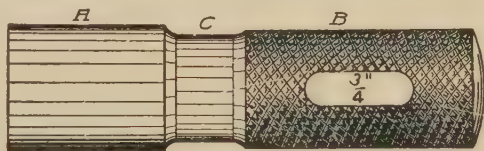


Fig. 413. Typical Plug Gage

Casehardening Machine-Steel Gages. When plug gages are made of machine steel, they should be casehardened in the following manner: They may be packed as for pack hardening, that is, in charred leather. They should run in the furnace for seven or eight hours after they are red hot. The box should then be taken from the furnace and allowed to cool, after which the gage, enclosed in a piece of tube, may be heated in an ordinary fire. When it reaches a low red heat, it should be plunged into a bath of raw linseed oil. It will not be necessary to draw the temper, and the danger of alteration as it ages is done away with.

The reason for not hardening when the gage has run the required length of time in the furnace, is that the effect of the second heat is to refine the steel, making the grain more compact, like properly hardened tool steel, thus increasing its wearing qualities.

Grinding. When grinding a gage of this description, it is advisable to use a grinding machine having a supply of water running on the work to keep it cool, but if this form of grinder is not available, the gage should not be heated any more than is necessary. It should be measured while cool, as steel always expands from the action of heat, and if ground to size when heated, would be too small after cooling.

If possible, a form of grinder having two dead centers should be used—that is, one in which neither center revolves. This is mentioned on account of the tendency in some shops where there is no universal grinder, and an engine lathe is to be used as a grinder, to select the poorest lathe in the shop for the purpose. Lathes that have been in use for some time are very likely to have become worn, so that accurate work is impossible; this is especially true



Fig. 414. Good Form of Lap for Cylindrical Surfaces

of the head spindle, which will duplicate its own inaccuracy on the piece being ground.

If obliged to do the work on a machine of this description, it is advisable to leave a trifle more stock for lapping than if a suitable grinder is used. A coarse wheel free from glaze should be employed to grind within .004 of finish size, after which a finer wheel may be substituted to grind to lapping size.

Lapping. A very simple method of making a lap for use on a cylindrical surface is shown in Fig. 414; this consists of a piece of cast iron having a hole bored a trifle larger than the size of the gage to be ground. It is split as shown, and closed by means of the screw *A*.

If there is much gage or other work requiring lapping, it is advisable to make a lap as shown in Fig. 415. The holder *A* has a

hole bored to receive the laps, which are made in the form of rings, split in three places, which fit the holder. One cut is carried through one wall; while the other two, commencing at the inside, terminate

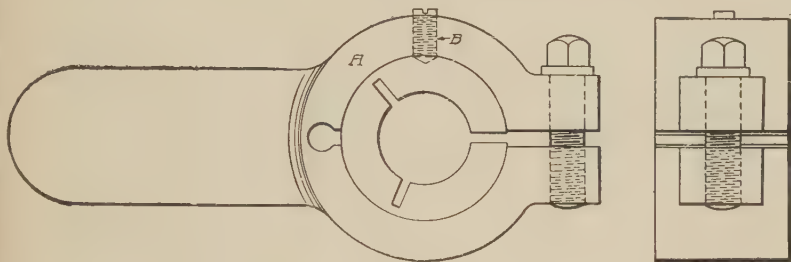


Fig. 415. Lap for Gages

a little distance from the outside surface. The laps may be held in place by means of the pointed screw shown at *B*.

The lapping should be done with flour emery mixed with oil. This operation has the effect of heating the gage to a degree that would make it unsafe to caliper, and on this account it is necessary to have a dish of water handy in which to cool the gage before measuring it. This water should not be *cold*, or incorrect measurements will result; it should be as nearly as possible the average temperature of the room in which it is to be used, about 70 degrees.

Grinding Off End. After the tool has been lapped to the required size, it may be placed in a chuck on the grinding machine and the end ground off to remove any portion that is slightly smaller than the rest of the gage, as the lapping is likely to grind the extreme end slightly tapering. In order to save time when grinding the end,

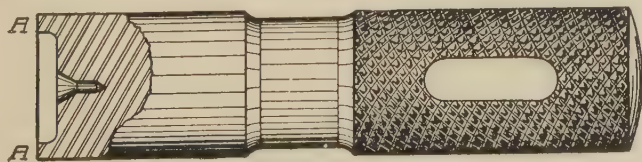


Fig. 416. Lap with Cuppea End Which Is Later Ground Off

the gage may be made as shown in Fig. 416. The sectional view shows the end cupped in, leaving a wall $\frac{1}{16}$ inch to $\frac{1}{8}$ inch thick, according to the size of the gage, the larger sizes having the thicker

walls; the cupping should be about $\frac{1}{16}$ inch deep and the corner left slightly rounded, as shown.

Another method is to cut a groove with a round-nosed cutting-off tool, leaving a disc on the end, Fig. 417. If the gage has its end

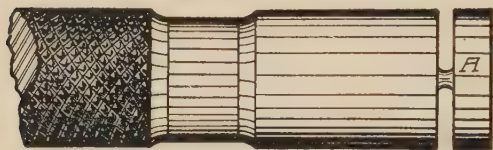


Fig. 417. Gage with Disc on End Which Is Broken Off and Ground Down

shaped as in Fig. 416, the projecting portion, *AA*, is ground away until the end of the gage is straight across. In case the gage is made as shown in Fig. 417, the

disc *A* is broken off and the end ground as described.

Ring Gages. *Ring gages* are intended for use on cylindrical pieces of work. Those which are smaller than one inch in diameter are generally made of a solid piece of tool steel, or machine steel which is casehardened. For a gage one inch or larger, custom varies, some tool-makers making it of a solid piece, while others make the body of cast iron or machine steel, into which is forced a hardened steel bushing which is the gage proper.

Boring Holes. It is advisable, when making a solid gage, to use a piece of steel somewhat longer than finish dimensions, as shown in Fig. 418, the dimension *A* representing the finish length

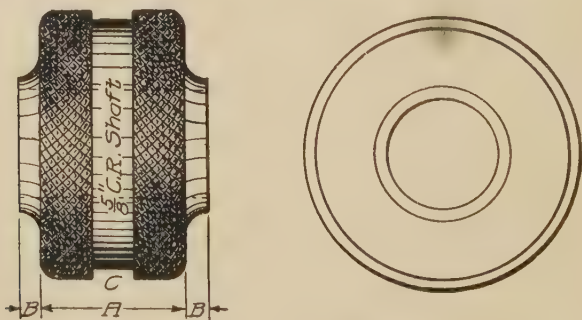


Fig. 418. Ring Gage

of gage, and the projections *BB* being left until the gage is lapped to size. The hole should be bored somewhat smaller than the finish size, in order to allow for grinding and lapping. If a grinder having an internal grinding attachment is not available, the allow-

ance should be much less than if it were possible to grind the walls of the hole. If the gage is to be ground to size, an allowance of .005 inch will be about the proper amount; if not to be ground and the hole is bored straight and smooth, an allowance of from .0015 to .002 inch should be made; but the amount left cannot be given arbitrarily, as much depends on the condition of the hole and the care used in hardening.

Hardening. After the hole has been bored, the blank may be placed on a mandrel, the ends shaped as shown in Fig. 418, the outside diameter turned and knurled, and the portion *C* necked to the bottom of the knurling. The size and any distinguishing marks may be stamped on this necked portion as shown. The gage is now ready for hardening, and much the best results are obtained from pack hardening. If this method cannot be used, the gage should be carefully heated in a muffle furnace or in a piece

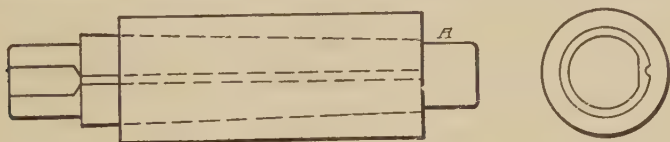


Fig. 419. Lead Lap on Mandrel

of gas pipe or iron tube in an ordinary fire. When it reaches a low uniform heat, it should be plunged into a bath of brine and worked around so that the bath may circulate freely through the holes. Excellent results follow if a bath is used having a jet of brine or water coming up from the bottom and passing through the hole with some force, in order to remove any steam that may be generated.

Grinding. If it is considered necessary to allow the gage to season, the hole may be ground enough to remove part of the allowance, and the gage laid away. If it is not considered necessary to do this, it may be ground .001 or .0015 inch smaller than finish size to allow for lapping.

Lapping. When lapping a ring gage to size, it is necessary to use a good lap. A poor lap is the cause of many of the failures when attempting to do satisfactory work of this description.

When a grinder with an internal grinding attachment is not available, and it is found necessary to leave considerable stock in the hold for lapping, many tool-makers claim best results from using two

laps—the first, a *lead lap*, for removing most of the stock, and the second, a *cast-iron lap*, for finishing the hole to size. In either case, the lap should be in the form of a shell which should be held on a taper mandrel when in use. Fig. 419 shows a lead lap on a mandrel as described.

The mandrel should be made with the ends somewhat smaller than the body, which should be tapering, in order that the lap may be expanded as it is driven on. A groove is cut the entire length of the body with a convex milling cutter, or it may be cut in the shaper or planer, holding the mandrel between centers, or in the

vise, cutting the slot with a round-nosed tool. A mold for casting the lead to shape may be made of two pieces of wood an inch or two longer than the desired length of lap, which itself should be three times the length of the hole in the gage. The two pieces of wood should be clamped together, and the hole bored with a bit about $\frac{1}{8}$ inch larger than the diameter of the finished lap; after boring to the required depth, a bit should then be used the size of the projection on the small end of the mandrel. The hole bored with this bit should be a trifle deeper than the length of the projection. After the hole has been bored in the mold, as described, the mandrel may be put in position, Fig. 420, with the mold vertical.

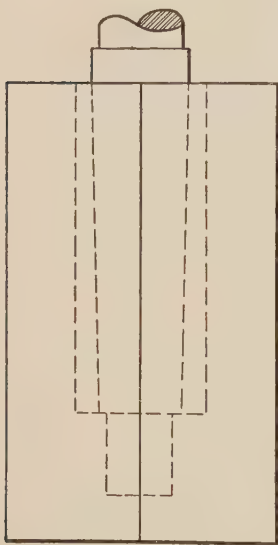


Fig. 420. Mandrel in Mold

Two narrow strips of wood or metal are placed on top of the mold to hold the mandrel central and the lead is poured. In order that the lead may run well, it will be necessary to heat the mandrel somewhat; this should be done before putting it in the mold. After the lead has become cool, the mold may be opened, and the casting removed. It should be placed in the lathe on the mandrel, and turned to a size .001 inch smaller than the hole in the gage; it may then be charged with fine emery and oil.

For finishing the hole to size, or lapping a hole ground nearly to size, it is advisable to use a lap made of harder material than lead;

for this purpose fine-grained cast iron answers admirably, although copper is preferred by some. In order to make a cast-iron lap, a mandrel is necessary, with a taper from $\frac{1}{8}$ to $\frac{3}{16}$ inch per foot of length. The slight taper is used in order that the lap may not increase its size too rapidly when driven on the mandrel. The cast-iron lap (sleeve) should be bored with a taper corresponding to the taper of the mandrel, after which it may be forced on the mandrel and turned to size and split as shown in Fig. 421. One slot should extend through the wall as shown at *A*, while the other two slots *BB* extend deep enough to allow the lap to expand readily. Before finishing the hole to size, the lap should be forced a trifle farther on the mandrel, and trued in the grinder, an emery wheel being

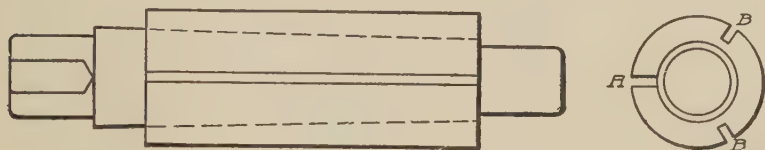


Fig. 421. Lap Forced on Mandrel and Split

used to cut the lap. The lap should be perfectly round and straight, in order to produce true holes. For the finish lapping, the finest of flour emery should be used.

Finishing Gage. The same precautions should be observed while cooling the gage before trying the size of hole, as were noted for plug gages. In order to clean the gage of the oil and emery, it should be dipped in a can of benzine, which readily removes any dirt. Extreme care must be exercised when washing work in benzine, that it is not brought into the vicinity of a flame of any kind, as benzine is extremely inflammable, and very difficult to extinguish if it becomes ignited; should it become ignited, it can be extinguished with a piece of heavy sacking.

The ring should be fitted to the plug gage which has previously been finished to the correct size. It must be borne in mind that the temperature of the plug and ring should be as nearly as possible the same when tested.

Snap Gage. This form of gage is used more extensively than any other for outside measurements. It is extremely useful in gaging a dimension between two shoulders as shown at *A*,

Figs. 422 and 423; in the former case, the piece being machined is flat, while in the latter it is cylindrical.

A snap gage may be designed to meet the requirements of the particular piece of work. When it is intended for use on a cylindrical piece, the opening should be made a trifle deeper than one-half



Fig. 422. Flat Piece Easily Gaged with Snap Gage

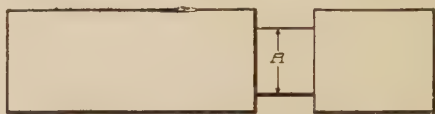


Fig. 423. Cylindrical Piece Adapted to Use of Snap Gage

the diameter of the piece to be measured, when it is intended for flat work, the depth of the slot depends on the nature of the work.

Snap Gages for Cylindrical Work. A gage of this type is shown in Fig. 424, *A* representing the cylindrical piece to be gaged. When making this gage, the stock should be blocked out somewhat near to shape and annealed; after annealing, the sides may be made flat and parallel, and the size and any distinguishing marks stamped as shown; the gage part may then be worked to a size from .008 to .010 inch smaller than finish, to allow for grinding. The outer edges should be rounded somewhat to prevent cutting the hands of the operator.

Some tool-makers harden only the prongs that come in contact with the work, while others harden the entire tool. If the contact points alone are to be hardened, the heating can best be done in a crucible of red-hot lead; if this is not at hand, pieces of flat iron may be placed, one on each side of the gage, allowing the ends to be hardened to project beyond the pieces; the whole may now be grasped in a pair of tongs and placed in the fire. The points will reach a hardening heat before the portion between the flat

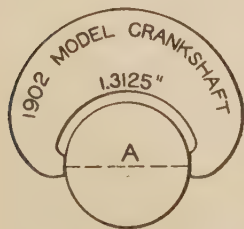


Fig. 424. Snap Gage

pieces is much affected. The gage may be plunged in water or brine to harden. If it is considered advisable to harden the gage all over, it should be heated very carefully in the fire, so that the blast does not strike it, and turned frequently to insure a uniform heat. When it reaches a low red heat, remove it from the fire and plunge

it into the bath. If the gage is quite thin, a bath of oil will harden it sufficiently; if it is dipped in water or brine, the bath should be warmed somewhat in order to avoid, as much as possible, any tendency to spring.

After hardening, the gage is ground to size .0005 inch smaller than finish and lapped to size; the method used in grinding gages of this character will be described later.

Male Gages for Testing Snap Gages. In order to be able to give gages the correct size, it is



Fig. 425. Male Gage

often necessary to make male gages, the simplest form of which is shown in Fig. 425. It is a flat piece of tool steel, made slightly small on one end to avoid grinding to size the entire length. After the large end has been hardened, it is ground to size and the gage is then ready for use in testing the size of the female snap gages while the latter are being lapped to size, or when being ground, if lapping is not considered necessary. When it is necessary to make a snap gage for measuring two or more dimensions on a piece of work, it may be made as shown in Fig. 426. Fig. 427 represents the piece to be gaged.

After cutting off the steel for the gage, the sides should be planed to remove the skin. One of the flat surfaces may be colored either

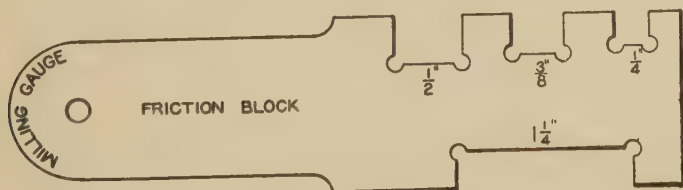


Fig. 426. Snap Gage Giving Several Measurements

with blue vitriol or by holding it over a fire until the surface becomes blue. The handle and the openings that constitute the gages can then be laid off on the surface. After milling the handle to shape, the holes shown at the corners of the openings may be drilled. These holes facilitate the operations of filing and grinding, particularly the latter. The openings may be milled or planed to a size about

$\frac{1}{32}$ inch smaller than finish, and the gage is ready for annealing, after which the two flat surfaces may be planed or filed until flat and parallel. The name of the piece to be gaged and the size of the openings may be stamped as shown. If the tool is intended

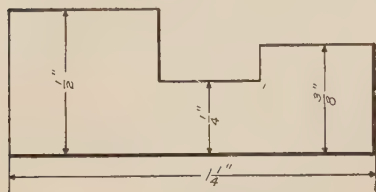


Fig. 427. Friction Block

for gaging work where a few thousandths of an inch either way would make no particular difference, it is customary to make the openings to the given sizes before the gage is hardened. However, if the gage must be exact to size, it is necessary to leave from .003 to

.005 inch on each measuring surface, to allow for grinding. If it is desirable to have the gage retain its exact size for any considerable length of time, it will be found necessary to finish it to size by lapping after it is ground.

Grinding Snap Gages. A snap gage may be held in a vise on the universal grinder when the openings are ground to size, provided it is held in such a way that it cannot spring. If sprung in any manner while being held, it would assume its normal shape when taken from the vise, and consequently the measuring surfaces would not

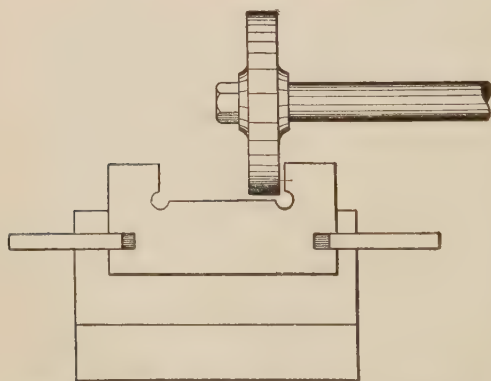


Fig. 428. Snap Gage Clamped in Vise for Grinding

be parallel. As this would destroy its accuracy, it is highly important that the measuring surfaces of the openings be parallel.

A snap gage may be clamped to an angle iron held in the vise while grinding, Fig. 428, or it may be clamped to a piece of machine steel or cast iron centered,

Fig. 429. This holder should be placed between the centers of the grinding machine.

If the opening whose gaging surfaces are to be ground is of sufficient width, an emery wheel of the form shown in Fig. 430 may

be used; or a wheel may be recessed on its sides as shown in Fig. 431. If the wheel is of the form shown in Fig. 430, it will be necessary

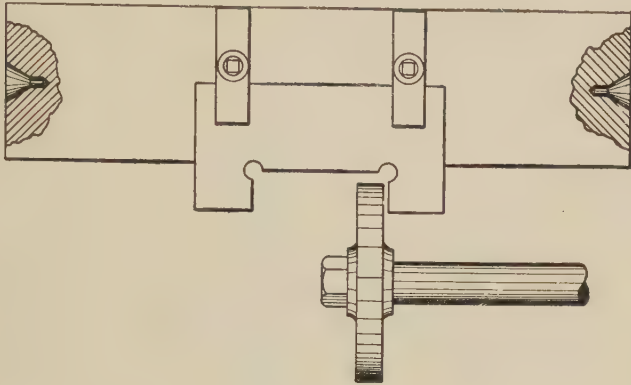


Fig. 429. Snap Gage Clamped to Centered Piece

to remove it after grinding one wall of the opening and to reverse it to grind the other. If, however, the opening is too narrow to allow this type of wheel, a very thin wheel may be made to answer the purpose, but it will be necessary to swivel the head of the grinder a little, in order that the wheel may touch the surface to be ground only at the corner of the wheel. An engine lathe or a bench lathe can be substituted if a grinding machine is not available. If the lathe is provided with a grinding attachment, the holder to which the gage is attached may be placed between the centers of the lathe, and the grinding attachment used in the ordinary manner. If the lathe is not provided with a grinding attachment, the emery wheel may be mounted on an arbor between the centers of the lathe. The arbor may be driven from any accessible pulley, either on some overhead countershaft or else on some machine whose driving pulley is in line with a small pulley on the arbor. If



Figs. 430 and 431. Typical Wheels for Grinding Gages

this method is used, it will be necessary to have hardened centers in both head and tail spindles of the lathe.

A thin wheel used in grinding the surfaces of a narrow opening necessitates that the tail center of the lathe be set over each way to give the desired amount of clearance to the side of the emery wheel. The holder mentioned may be fastened to the tool rest, or the gage

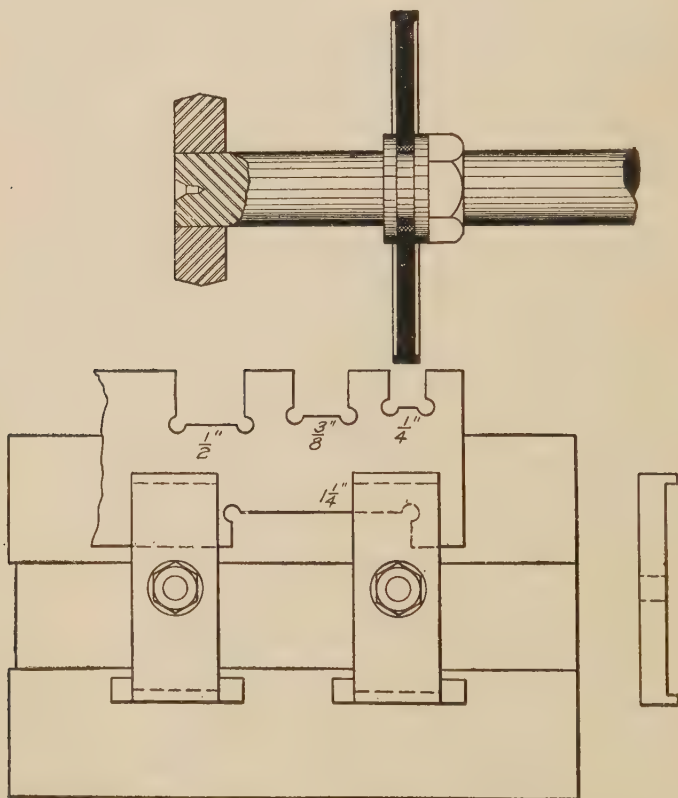


Fig. 432. Method of Fastening Gage for Grinding with Thin Wheels

may be fastened to the rest, Fig. 432. At the right is shown a side view of one of the straps used to hold the work to the rest while grinding; the center is represented as being cut away in order that it may bear at its ends, thus removing any chance of its tipping the work that is being ground.

Lapping Snap Gages. Where it is essential that gages retain their exact size for a considerable length of time, the gaging surfaces

must be lapped to size after grinding. The surface left by the emery wheel, even when the utmost care is used, consists of a series of small ridges or irregularities which wear away as the gage is used and leave the opening too large. Lapping the gaging surfaces with oil and emery grinds these minute particles away and produces a perfectly flat surface, thereby increasing the durability of the tool.



Fig. 433. Lap for Gaging Surfaces

A convenient form of lap to use on snap gages is illustrated in Fig. 433. It consists of a piece of copper or brass wire, bent as shown; the surface *A* is filed or hammered flat, and is charged with some abrasive material, as emery. Extreme care must be used in lapping the surfaces, that they may remain perfectly flat and parallel. Unless the operator has had considerable experience in this particular work, he will be likely to cut the edges away more than the center. To avoid doing this, pieces of hardened steel may be clamped to each side of the gage before grinding, Fig. 434. As the tendency when lapping is to make the outer edges round, the portions rounded

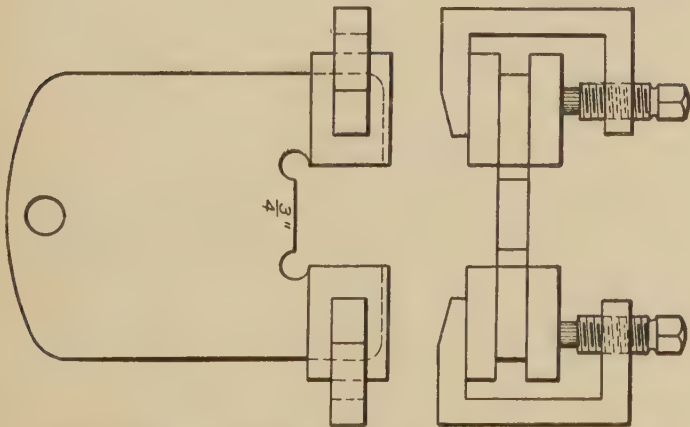


Fig. 434. Method of Clamping Pieces on Gage to Prevent Rounding Edges

will be the edges of the pieces clamped to the gage. After the gage has been lapped to size these pieces may be removed.

Adjustable Snap Gage. Snap gages that are in constant use soon wear to an extent that renders them useless, making it necessary

to close them in, and grind and lap them to size again, or else to replace them with new ones. This tendency to wear, and the consequent labor and cost of resizing or replacing, has caused the adoption of a style of snap gage whose size can be altered when necessary; this form of gage is styled an adjustable snap gage.

The method of adjustment differs in different shops. Fig. 435 represents a form of adjustable snap gage which is not expensive and which gives excellent results, because of the ease of adjustment. After blocking out the gage somewhere near to shape, the screw hole for the adjusting screw *C* should be drilled and tapped, and the slot milled for the adjustable jaw. The jaw should be made, as shown, with a slot, through which the binding screw *D* may pass. The jaw should fit snugly in the slot in the frame, and be placed in

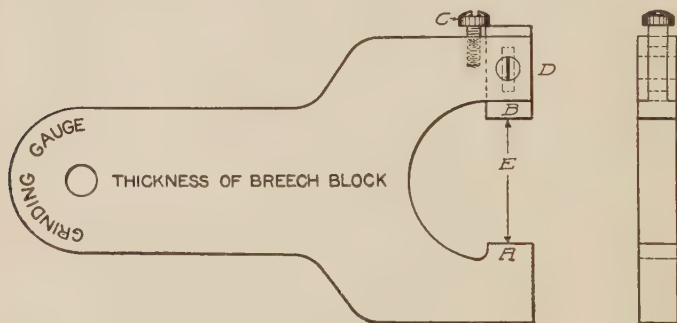


Fig. 435. Adjustable Snap Gage

position after the name and any distinguishing marks are stamped. The aperture *E* should be worked to a size that is from .010 or .015 inch smaller than finish. The adjustable jaw *B* may then be removed, and the gaging, or contact, surface hardened. Care should be taken not to harden the entire length, or a crack may appear in the sharp corners on account of the unequal size of the two parts. In order to heat the contact surface and not to heat back into the sharp corners, the face may be immersed in red-hot lead just long enough to heat the face sufficiently; or the smaller portion may be held in a pair of tongs, letting the end of the jaws come against the shoulders of the piece. It may then be heated in a gas jet or ordinary fire. For most purposes it will be necessary to harden the gage all over; if the gaging portions *A* and *B* are hardened, this will be found

sufficient. After hardening, the gage may be assembled, ground, and lapped, as already explained.

Limit Gages. Where it is not necessary that work be of exact size, and a small degree of variation is permissible, limit gages are used. They prevent a waste of time in attempting excessive accuracy, yet leave the work so that the corresponding parts when brought together will fit well enough to meet requirements. These gages are also valuable in roughing work for finishing. When so used, practically the same amount of stock is left on each piece, thus facilitating the finishing process.

If a cylindrical piece is to go in a reamed hole, and the piece fits well enough for all requirements when .003 inch smaller than the size of the hole, it is folly to spend the time necessary to get a more exact fit. The amount of variation allowable must be decided in each case; on one job a limit of variation of .001 inch might be all that could be allowed, while on another piece of work .010 inch might be allowable.

In deciding the allowable limit of variation, it is advisable, where possible, to take into consideration the natural changes that

take place in the gage from wear. For instance, suppose a piece of work .250 inch in diameter just fills the hole for which it is designed,

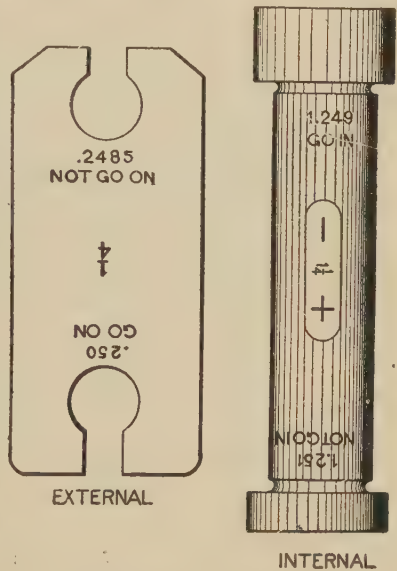


Fig. 436. Simple Snap and Plug Limit Gages



Fig. 437. Plug Gage

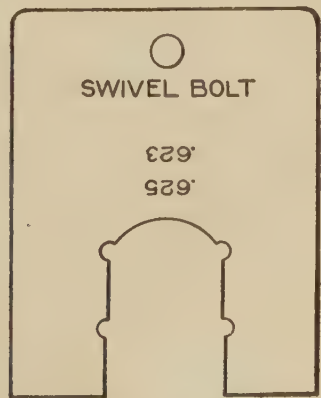


Fig. 438. Snap Gage

and a limit of .0015 inch is allowable; if the piece is from .2485 inch to .250 inch in diameter, it would be folly to make the large end of limit gage for this work .250 inch, as there would be no allowance for wear of either the external or internal gage. The general instructions given for making plug gages and snap gages apply to limit gages of the same character.

Illustrations of Snap and Plug Limit Gages. Fig. 436 gives an idea of one form of snap and plug gage used for external and internal measurements; however, it is not necessary to make them of the styles shown. The plug gage may be made as shown in

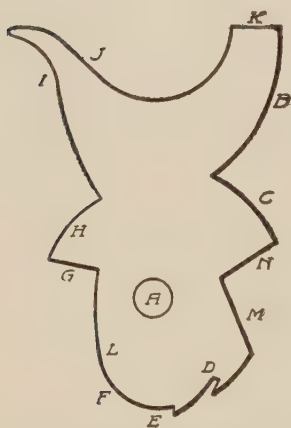


Fig. 439. Diagram of Gun Hammer

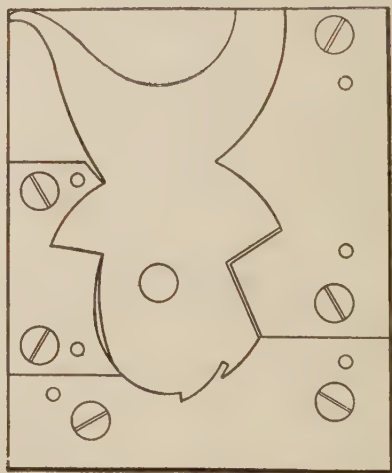


Fig. 440. Receiving Gage for Gun Hammer

Fig. 437; while the snap gage may be made like the one illustrated in Fig. 438.

Receiving Gages. When it is essential that the various working points of a tool, part of a machine, or apparatus shall be in exact relation to one or more given points, a receiving gage is used. This gage, as the name implies, is made to receive, or take in, the work; that is, the piece of work is placed in the gage, and the location of the different points is determined by the eye.

Fig. 439 shows a gun hammer, while Fig. 440 represents a receiving gage for accurately gaging the points C, D, E, F, G, and H, in relation to the fulcrum screw hole A and the face B. These points must also be in exact relation to each other—hence the

necessity for a gage of this character. When making the gage, it is customary in most shops to gage only those parts that must be located accurately with relation to some other point or points.

Locating Points. In the case of the gun hammer under consideration, the fulcrum screw hole *A* must be the main working point, because when in use the gun hammer is pivoted at this point, and, consequently, every point must be in exact relation to this hole; the point of next importance is the face *B* which strikes the firing pin. In order that the face of the hammer may be the proper distance from the firing pin when half-cocked or full-cocked, it is necessary that the half-cock notch *D*, and the full-cock notch *E* be correctly located with regard to the face of the hammer. They must also be in exact location as regards the fulcrum screw hole *A*. If the main spring is to exert the proper amount of force on the hammer, it is necessary that the spring seat *G* be accurately located. As the portions marked *C* and *H* are intended just to fill the opening in the gun frame when the hammer is in any position, it is necessary that they be located the proper distance from the center of the fulcrum screw hole *A*; hence the need of a gage that will determine the exact location of all points as related to *A* and *B* and to each other. As the portions marked *I*, *J*, *K*, *L*, *M*, and *N* must be in precise location to the other points or to each other, they are gaged with a separate tool because each additional gaging point complicates matters.

Making Base for Gage. When gages of this character are being made, a piece of machine steel is usually taken for the base; this is planed to size and ground or filed for finish; a hole is drilled and reamed to receive a pin the size of the fulcrum screw hole. This pin is made of a piece of drill rod a few thousandths of an inch larger than the desired pin. The piece of drill rod should be long enough to be held in the chuck of the grinding machine, and should be cut of the proper length, as shown in Fig. 441. The short end should be hardened and the temper drawn to a straw color, after which the pin may be placed in the chuck and ground to the desired size. It may then be broken off and the end ground; this can be done by holding the pin in the chuck, leaving the broken end out in order that it may be ground square; the pin should then be forced to place in the hole in the base.

Shaping Gage. The gage proper may be made of one plate worked to the proper shape, but better results follow if it is made in three pieces, as shown in Fig. 440, on account of the tendency of the plate to spring when hardened. The plates may be made either



Fig. 441. Base Pin for Receiving Gage

of tool steel or machine steel. If of tool steel, they should be machined all over and thoroughly annealed, then planed or milled to thickness. One surface should be colored by the blue vitriol solution, or the pieces may be heated until a distinct blue color appears; the desired shape should be marked on the colored surface, and the pieces machined and filed until they fit the model, the necessary degree of accuracy being determined by the nature of the work.

Fitting to Base. After the pieces are properly fitted to the model, they may be attached to the base by means of the fillister head cap screws shown. The model should be laid on the base having the fulcrum screw hole on the pin, and when in its proper

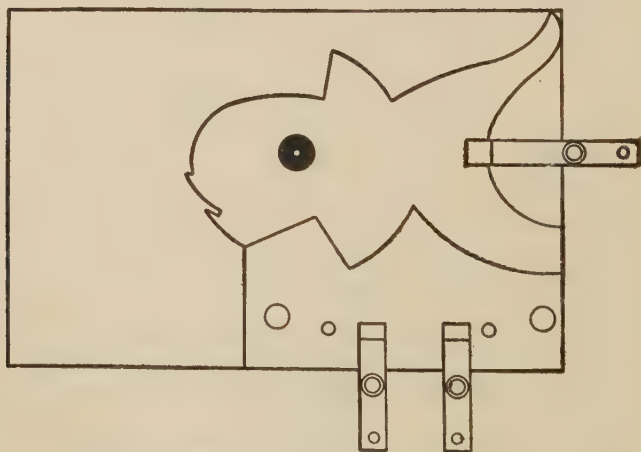


Fig. 442. Model of Gun Hammer Clamped in Place

location, it may be clamped, as shown in Fig. 442. The sections of the gage, which should have been previously drilled for the screw and dowel pins, may now be clamped to the base in their proper positions. After drilling, the holes in the base may be tapped,

and the screws put in place. Slight alterations in any of the shapes are readily made if necessary, as the plates can be moved a trifle since the bodies of the screws need not fit tightly in the holes in the plates. The dowel pinholes should not be transferred into the base until after the plates are hardened.

Hardening. The plates may now be removed and hardened. If of machine steel, they may be casehardened, and dipped in oil rather than water. If made of tool steel, best results follow if they are pack hardened; they should be run from 1 hour to $1\frac{1}{2}$ hours after becoming red hot, and then dipped in raw linseed oil. If the process of pack hardening cannot be used, satisfactory results may be obtained by heating the plates in a tube in an open fire, or placed in the muffle of a muffle furnace. When red hot sprinkle a small

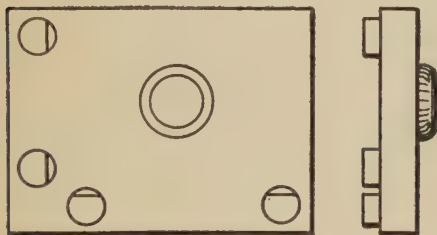


Fig. 443. Locating Gage

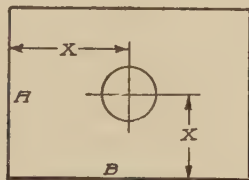


Fig. 444. Piece with Hole to Be Located

quantity of finely powdered cyanide of potassium, or a little yellow prussiate of potash, on the contact surface; place it in the fire again; bring it to a low red heat, and plunge it into a bath of oil.

Attaching to Base. After being hardened, the plates may be attached to the base by means of the screws. If any of the gaging points have become distorted during the hardening, they may be brought to the proper shape by oil-stoning. When the plates are properly fitted and located in their exact positions, the dowel pin holes may be transferred into the base and the dowel pins put in place.

Locating Gages. This form of gage is used for determining the location of one or more holes in relation to another hole, a shoulder, a working surface, or any similar measurement.

Fig. 443 illustrates a gage for showing the proper location of the hole from the edges *A* and *B*, Fig. 444. It consists of a base

having four pins for the edges *A* and *B* to rest against. These pins are flattened on the contact edges to prevent wearing. The piece of work to be gaged is placed in position and clamped to the gage with machinist's clamps, Fig. 445, and the gage is fastened

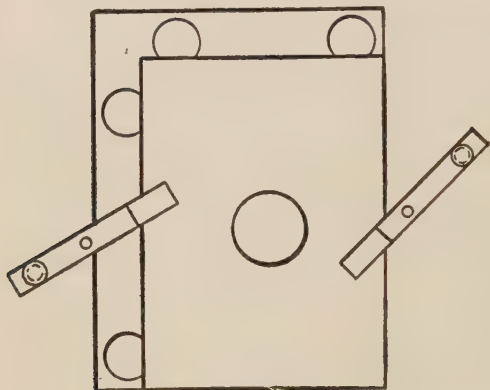


Fig. 445. Piece Clamped in Gage

to the faceplate of the lathe in such a manner that the work can be removed without disturbing the location of the gage.

A short plug, fitting very accurately, is then inserted in the hole in the model. By means of a lathe indicator, the gage can be located so that the plug runs perfectly true. When this has been accomplished, the model may be removed and the bushing hole drilled and bored to size, after which the bushing may be made, hardened, ground to size, and forced to place. The location of the drilled hole may be tested by placing the piece of work on the gage against the pins, and entering the

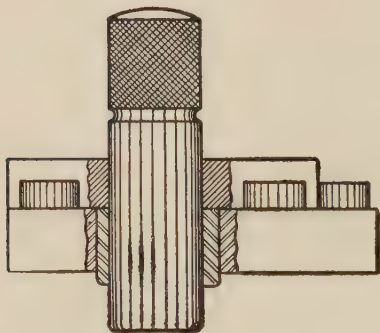


Fig. 446. Gaging Hole

gage pin in the hole in the work and bushing, Fig. 446. If the pin is a close fit in the holes, a very slight error in location may be detected. When a slight error is allowable, and it is not considered advisable to hold the location too close, the pin may be made a trifle small, thus transforming the gage into a limit gage.

If it is necessary to make a locating gage, for testing the center distance of two holes, one pin may be made removable, while the other is rigidly fixed, as shown at *C*, Fig. 447. If the gage is made with both pins fixed, and the pins are a good fit in the holes, it is a difficult operation to remove the piece of work. Withdrawing

one pin allows the piece of work to be readily taken from the fixed pin.

When making a gage of the form shown in Fig. 447, the fixed pin *C* may be located by approximate measurements; but the hole should be drilled by some method that insures the pin standing perfectly square with the base of the gage. If a small limit of variation is permissible in the center to center measurement *A*, the model may be placed on the gage with the large hole on the fixed pin *C*, and the location of the hole for the movable pin may be transferred from the model by drilling and reaming. If extreme accuracy is essential, it will be advisable to clamp the model to the

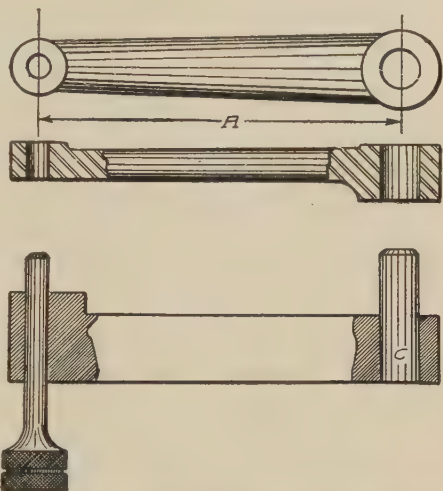


Fig. 447. Simple Form of Locating Gage Showing Method of Use

gage as described, then to fasten the gage to the faceplate of the lathe, place an accurately fitting pin in the small hole in the model, and by means of a lathe indicator locate the gage so that the pin

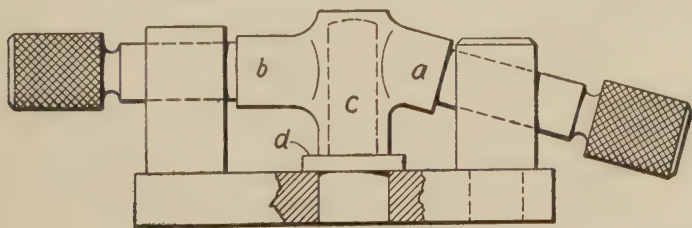


Fig. 448. Gage for Measuring Locations and Directions of Holes

runs perfectly true. The model may then be removed and the hole drilled and bored to size.

Locating gages are made to measure the location of one or more holes from another hole or shoulder, or both. Fig. 448 is a gage to measure the locations of holes *a* and *b* from the hole *c* and

shoulder *d*. The hole *c* is set on a stud solid with the base, and *a* and *b* are gaged by means of the hardened and ground pins shown.

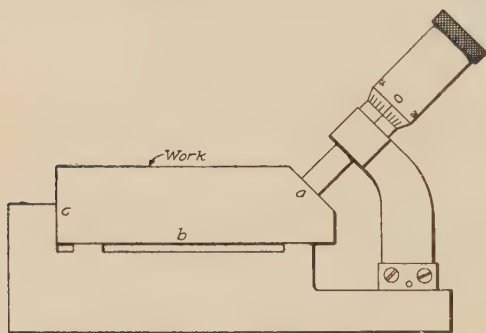


Fig. 449. Micrometer Gage

Micrometer Gage.

Micrometer locating gages are very commonly used in many shops. They are especially valuable for measuring such pieces as require very close watching, or where a certain variation is permissible, for by means of micrometer readings the amount of variation

in thousandths of an inch is easily determined. Fig. 449 shows a micrometer gage used in measuring the angle surface *a* in connection with base *b* and shoulder *c*.

DRAW-IN CHUCKS

In many shops, the bench lathe plays a very important part in the making of all kinds of small tools. The lathes, being provided with draw-in chucks, allow the extensive use of drill rod when making reamers, counterbores, milling cutters, punches to be used in the punch press, and many other forms of tools. As the modern tool room bench lathe has a milling attachment and a grinding head, it is possible to turn up various forms of tools, and then to do such milling and grinding as is necessary.

While a lathe is usually equipped with an assortment of draw-in chucks to hold stock of various sizes, it is necessary many times to replace a chuck or to make one of special size to accommodate a job that cannot be done in any chuck on hand.

Directions for Making. The methods employed in various shops for making draw-in chucks differ materially, but the following method will be found very satisfactory and does not necessitate special tools:

A piece of tool steel somewhat larger than the largest portion of finished chuck is cut off from $\frac{3}{16}$ inch to $\frac{1}{4}$ inch longer than the finish dimension. After centering, the ends should be carefully

squared and a roughing chip taken. The large clearance hole should now be drilled by holding the end *F*, Fig. 450, in a center rest, and using a drill held in a chuck in the tail spindle of the lathe. Before removing the piece from the center rest, carefully countersink the outer end of the hole with a suitable tool to an angle of 60 degrees.

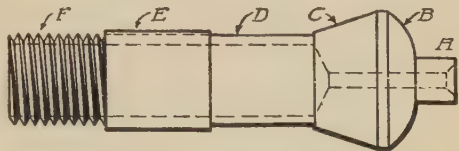


Fig. 450. Draw-In Chuck Blank

The piece is now placed between the centers of a lathe, the portions *B*, *D*, *E*, and *F* turned to finish size, and the thread at *F* cut to fit the threaded hole in the draw-in spindle. The portion *C* is left a little large to allow for grinding after the chuck is hardened.

The portion *A* is turned, as shown, to provide a center for use in turning and grinding; it also holds the chuck in shape when it is hardened as the slots do not extend the length of this portion. The spline cut to receive the feather in the spindle is now milled, the piece being held between the centers of the index head. After the burrs have been removed the piece is inserted in the lathe spindle, and the hole to receive the work is drilled and reamed to a size enough smaller than finish size to allow for grinding after the chuck is hardened.



Fig. 451. End of Draw-In Chuck for Large Drills

The piece is again placed between the index centers and the three slots cut, Fig. 451. As previously stated, these slots should not extend through the portion *A*, Fig. 450, but should be as shown in Fig. 451, and should clear the hole. The slots should extend into portion *E*, Fig. 450, a little way. The metal slitting saw used in producing the slots should be of as small diameter as can be conveniently used, and should not be too thick, as a thick cutter would, in the case of a chuck with a small hole, cut away all the hole. For chucks with large holes, a slot as shown in Fig. 451 works well; but, for chucks with small holes a comparatively thick saw may be used to cut the slot nearly to depth; then a thin cutter may be substituted to finish it as shown in Fig. 452. Before hardening, the

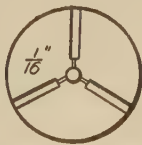


Fig. 452. End of Draw-In Chuck for Small Drills

size of the finish hole should be stamped on the face of the chuck. A finished chuck of this type is shown in Fig. 453.

An oven furnace provides an excellent means of heating for hardening. If an open fire must be used, the chuck should be placed in a piece of gas pipe, heated to a uniform low red, and plunged into a bath of lukewarm water or brine a little above the ends of the slots. The temper of the portions *B* and *C*, Fig. 450, should then be drawn to a brown, and the rest of the hardened part to a blue.

The chuck should now be placed between the centers of a universal grinder, or, in the absence of such a machine, in a grinding

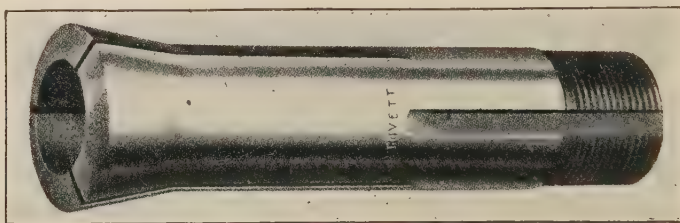


Fig. 453. Completed Draw-In Chuck

Courtesy of Rivett Lathe Manufacturing Company, Boston, Massachusetts

lathe, and the portion *C* ground to finish size and to fit the taper in the nose of the lathe spindle. If many chucks are made, it is advisable to grind to a gage; but, where there are only one or two, it is not necessary to go to the expense of a special gage.

After the portion *C* has been ground to fit, the chuck may be inserted in the spindle of the lathe, the hole ground to size, the portion *A* ground away, and the face polished. The chuck is now ready for use.

EXAMINATION PAPER

TOOL-MAKING

PART III

Read Carefully: Place your name and full address at the head of the paper. Any cheap, light paper like the sample previously sent you may be used. Do not crowd your work, but arrange it neatly and legibly. *Do not copy the answers from the Instruction Paper; use your own words, so that we may be sure you understand the subject.*

1. When making bushing holes in drill jigs by the method illustrated in Fig. 262, Part II, *why* are more satisfactory results obtained if the cutting end of counterbore is made in the form shown in Fig. 263?

2. State in your own words the reason for obtaining location of bushing holes in drill jigs by means of locating buttons and lathe indicator.

3. Why are drill jigs for permanent equipment provided with hardened steel bushings?

4. What is the objection to using the ordinary shop mandrel for holding bushings when grinding to finish size?

5. When drilling the block illustrated in Fig. 300, *why* is it advisable to first use the transfer drill shown in Fig. 303?

6. Explain the office of the guide and stop used on a punching-press blanking die.

7. When milling the opening of blanking die for use on punching-press work, if no milling cutter of the proper taper were available, and you were obliged to use a straight cutter, how would you get the desired clearance?

8. Why are the faces of punching-press blanking dies made shearing? When is it allowable? When not?

9. When hardening a blanking die for punching-press work *why* is it necessary to heat the die *uniformly throughout*?

10. Why are blanking dies sometimes made in the form of sectional dies?

TOOL-MAKING

11. When are punches made to *fit* the opening in a blanking die? When are they made smaller?

12. When making a die for use in punching a piece of irregular outline whose opposite sides are not alike, as shown in Fig. 331, why is it necessary to observe care when marking the face of the punch from the templet used in laying out the shape of the aperture in the die?

13. When is it necessary to place the stripper on the punch rather than on the die? Why?

14. When making bending dies of the description shown in Fig. 352, name the various points necessary to take into consideration.

15. When is it necessary to use gages?

16. Under what circumstances is it advisable to finish contact surfaces of gages by lapping? Why is it necessary?

17. Why should the ends of plug gages be left, as shown in Fig. 416 or Fig. 417, until the gage is lapped to size?

18. When *finish* lapping a ring gage to size why is it necessary to grind the lap perfectly round?

19. When are snap gages used? Why are they used in preference to a micrometer on ordinary work?

20. When making a snap gage of the description shown in Fig. 426, why is it necessary to leave a small amount of stock on each contact until after the gage is hardened?

21. When grinding the contact surfaces of snap gages, what points must be observed?

After completing the work, add and sign the following statement:
I hereby certify that the above work is entirely my own.

(Signed)

Aug 12, 1928



T4-AKC-138

